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Small Vessel
Fixed Fire Extinguishing Systems

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Small Vessel Fixed Fire Extinguishing Systems

By

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MIL Systems

December 2002

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Since some of the accepted measures in the industry are imperial, metric measures are not always used in this report.

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16. Abstract

Due to the high cost and poor availability of low-volume fixed fire extinguishing systems, numerous small vessel owners in Canada have fitted homemade systems on board their vessels using modified portable extinguishers connected to some form of fixed piping system. These homemade systems are not ULC-approved, Transport Canada – Marine Safety Branch surveyors have no guidelines on how to inspect them, and there is no guarantee that these systems would effectively extinguish a fire.

This report provides a detailed background on these issues by examining the Canadian and international regulations governing fixed fire extinguishing systems and by outlining the scope of the problem based on a survey of the small vessel fleet in Canada. It presents market research on fixed fire extinguishing systems that are available, and provides guidelines to vessel owners and to Transport Canada surveyors on the correct design, installation and inspection of these systems.

As a result of this project, ANSUL, a firm specializing in fire suppression, developed a small low-cost fixed fire extinguishing system and had it ULC tested and approved. Two of these systems were installed on small fishing vessels and were successfully tested. The description and results of these tests are provided in this report. The ANSUL system is now commercially available to small vessel owners.

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16. Résumé

En raison du coût élevé et de la disponibilité limitée des systèmes d'extinction fixes à faible volume, de nombreux propriétaires de petits bateaux, au Canada, ont installé des systèmes de fabrication artisanale dans leurs bateaux : l'installation consiste en un extincteur portatif modifié, raccordé à des canalisations fixes de distribution. Ces systèmes bricolés ne sont pas approuvés par les ULC. Les experts maritimes de la Direction générale de la sécurité maritime, à Transports Canada, ne disposent d'aucune ligne directrice pour faire l'inspection de ces systèmes et il n'existe pas de garantie de leur efficacité à éteindre un feu.

Le rapport donne un aperçu détaillé de ces questions, qu'il examine sous l'angle des réglementations canadienne et internationales visant les systèmes d'extinction fixes, en plus de faire ressortir la portée du problème d'après une enquête sur la flotte canadienne de petits bateaux. Il présente les résultats d'une étude de marché des systèmes d'extincteurs fixes et fournit des directives aux propriétaires de bateaux et aux experts maritimes de Transports Canada, sur le calcul, l'installation et l'inspection des systèmes offerts dans le commerce.

Par suite de ce projet, la société ANSUL, spécialisée dans les systèmes de suppression d'incendie, a mis au point un petit appareil d'extinction à faible coût et l'a soumis à des essais et à l'approbation des ULC. Deux systèmes ont été installés à bord de petits bateaux de pêche et ils ont été soumis avec succès aux essais requis. Le rapport renferme une description et les résultats de ces essais. Les propriétaires de petits bateaux peuvent maintenant se procurer le système ANSUL dans le commerce.

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Due to the high cost and poor availability of low-volume fixed fire extinguishing systems, numerous small vessel owners in Canada have fitted homemade systems as fixed fire systems using portable extinguishers connected to some form of fixed piping system. These homemade systems are not ULC approved. Transport Canada – Marine Safety Branch surveyors have no guidelines on how to inspect them and, perhaps most importantly, there is no guarantee that these systems would be effective in extinguishing a fire.

A detailed background on these issues is provided by examining the Canadian and international regulations governing fixed fire extinguishing systems and by outlining the scope of the problem based on a survey of the small vessel fleet in Canada. Market research is presented on fixed fire extinguishing systems that are available, and guidelines are provided for vessel owners and for Transport Canada – Marine Safety Branch surveyors on the correct design, installation and inspection of these systems.

As a result of this project, WMSEL, a fire specialising in fire suppression, developed a small low-cost fixed fire extinguishing system and had it ULC tested and approved. Two of these systems were installed on small fishing vessels in accordance with the guidelines and were successfully tested. The description and results of these tests are provided. The WMSEL system is now commercially available to small vessel owners.

Recommendations of this project are to prohibit the use of homemade fire extinguishing systems, which are based on modified portable fire extinguishers, and to encourage the use of low-cost ULC tested and approved systems that are now available.

[illegible] [illegible] [illegible] [

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DEFINITIONS

Presented below are some basic definitions of common terms relevant to CO_2 system design:

Local Application System	A system consisting of a supply of carbon dioxide arranged to discharge directly on the burning material.
Total Flooding System	A system consisting of a supply of carbon dioxide arranged to discharge into and fill to the proper concentration an enclosed space or enclosure about the hazard.
Free Efflux	When carbon dioxide is injected into a space, the displaced atmosphere is exhausted freely (through various small openings).
Low Pressure System	Carbon dioxide cylinders stored at -18°C (0°F); pressure when stored at this temperature is 2068 kPa (300 psi).
High Pressure System	Carbon dioxide cylinders stored at -21°C (-6°F); pressure when stored at this temperature is 5860 kPa (850 psi).

1. INTRODUCTION

Due to an absence of available fire extinguishing systems on the market, numerous small vessel owners in Canada have fitted homemade fixed fire extinguishing systems on board their vessels. These homemade systems are typified by one or more off-the-shelf portable extinguishers that have had their hoses cut and are connected to a piping system of galvanized pipe, household plumbing copper pipe or hose. The discharge bell from the portable extinguisher is connected at the end of the piping system.

The impetus behind this project was concern raised by Transport Canada surveyors regarding these homemade systems. Of particular concern were the following:

- *Underwriters' Laboratory of Canada (ULC) Approval:* All portable extinguishers sold in Canada must be ULC approved. However, if they are modified in any way ULC approval is voided; therefore, the portable extinguishers used in homemade systems are not ULC approved.

- *Safety and Reliability:* Portable extinguishers are not designed to be connected to fixed piping systems. Fixed fire extinguishing systems require engineering calculation to match bottles, control heads, piping system and discharge nozzles. Engineering ensures that proper pressure at the nozzle of a system provides regulatory-defined discharge time and flow rate.

- *Transport Canada Assessment:* Transport Canada surveyors are not trained as experts in gas system design for fire protection. Therefore, they are unable to assess the safety or reliability of homemade systems.

The purpose of this project was to assess and provide solutions for the concerns noted above. The project was divided into a number of distinct tasks as outlined below:

- Regulatory Review: A review of Canadian and international regulations to obtain an understanding of the regulatory requirements regarding fixed fire-extinguishing systems for small vessels.

- Vessel Surveys: Surveys conducted to inspect actual homemade extinguishing systems.

- Fleet Survey: An assessment of the number of small vessels in Canada that might have homemade extinguishing systems installed.

- Market Research: Research into the availability of viable extinguishing systems on the market.

- Development of Guidelines: Guidelines to assist Transport Canada surveyors in assessing homemade extinguishing systems.

- Field Testing: Testing of systems installed according to the guidelines to ensure predicted performance.

2. BACKGROUND

Firefighting professionals categorize fires into four types:

1) Class A: A fire involving ordinary combustibles such as wood, cloth, paper, rubber or some plastics. Extinguished with water, or multi-purpose dry chemical or foam type extinguishers.

2) Class B: A fire involving ordinary flammable or combustible liquids, flammable gases, greases or similar materials such as gasoline, oil, paint and natural propane gas. Extinguished with dry chemical, multi-purpose dry chemical, carbon dioxide, halon or foam type extinguishers.

3) Class C: Usually a Class A or B fire that also involves energized electrical equipment. Extinguished with dry chemical, multi-purpose dry chemical, carbon dioxide or halon extinguishers.

4) Class D: A fire involving certain combustible metals such as magnesium, sodium, potassium, etc. Extinguished with special dry powder extinguishers.

Regardless of the class of fire, the following elements must always be present to produce fire:

- Oxygen: Sufficient oxygen to sustain combustion
- Heat: Sufficient heat to raise the material to its ignition temperature
- Fuel: A fuel or combustible material

Oxygen, heat and fuel are frequently referred to as the Fire Triangle. Removing any of these elements will extinguish the fire. An inert gas, such as CO_2, extinguishes a fire by reducing the oxygen concentration to a point where the atmosphere will no longer support combustion. That is, CO_2 removes oxygen from the Fire Triangle. For most flammable liquids, reducing the atmospheric oxygen content from the normal 21% to 15% will extinguish the fire.

Shipboard fires are typically Class B or C fires. The most common fire-smothering gas used in fixed systems onboard ships is CO_2 because of its fire extinguishing efficiency, cleanliness and ease of application [1].

CO_2 is a colourless, odourless, clean, dry, electrically non-conducting, non-corrosive and non-deteriorating inert gas. CO_2 is approximately 50% heavier than air and is stored in high-pressure portable extinguishers at pressures between 750 and 850 psi (5.2 and 5.7 Mpa) at 70°C. CO_2 has a high expansion ratio of approximately 450:1 and, as such, the discharge from a storage cylinder is by force of its own expansion; pumps or other pressurizing mechanisms are not required. The temperature of CO_2 discharging from a nozzle is approximately -100°F (-73°C). Due to condensation, the discharge creates a cold fog, which generally dissipates after a few minutes. CO_2 vaporizes completely on discharge; consequently, the cost associated with clean-up is negligible.

However, CO_2 is hazardous to personnel. At concentrations of 3 to 4% by volume in air, breathing rate increases and headaches are common. At concentrations of 9%, disorientation, visual disturbance, ringing in the ears and tremors precede loss of consciousness in a matter of minutes. At concentrations of about 20%, death will follow in 20 to 30 minutes.

After the introduction of halon gas 10 to 15 years ago, halon-1301 quickly became the common solution to small vessel fixed firefighting needs. Halon has similar properties to CO_2 (i.e. electrically non-conductive, dissipates quickly, leaves no residue, etc.) but is relatively safe for human exposure. As halon became the first choice for small vessel fixed firefighting, the demand for small volume fixed CO_2 cylinders decreased; cylinders of less than 25 lb. became difficult to obtain.

The effect of halon on ozone depletion led the United Nations Environment Programme (UNEP) to place strict controls on halon usage [2]. As a result, halon ceased to be a choice for new shipboard firefighting systems. Recycled halon is still available for existing systems; however, this option is becoming increasingly less cost effective.

The ban on halon and the difficulty in obtaining small fixed CO_2 cylinders created a problem for small vessels requiring low volume fixed firefighting systems. One solution to this problem was to use portable CO_2 fire extinguishers, which were readily available in small sizes, in place of fixed cylinders. Although small volume fixed cylinders have recently become available, portable CO_2 extinguisher based fixed firefighting systems are still being installed due to their low cost.

Modification of a portable extinguisher for a fixed firefighting system typically entails cutting the discharge hose, connecting it to a longer run of pipe and re-connecting the bell. Generally, no modifications are made to the operating head. Nevertheless, there are a number of problems that arise from such modifications:

- ULC approval of the portable extinguisher is void if the extinguisher is tampered with in any way.
- Unless the fixed system is designed correctly, giving due consideration to release pressure, piping design and deck/bulkhead penetrations, etc., then the functionality and performance of the system may be uncertain.
- Regulatory requirements (concentrations, etc.) may not be met by modified systems.
- There is confusion among surveyors concerning certification of these systems due to a lack of adequate standards. That is, there are no guidelines for surveyors on what is acceptable and what is not acceptable.

East coast fishing vessels provide a good practical example of the problem at hand. In-shore/near-shore fishing vessels 65 ft. (19.8 m) in length require a fixed fire extinguishing system. Depending on machinery space volume, these systems usually consist of two 50 lb. or two 75 lb. fixed CO_2 cylinders. Costs are about $5,000 for a system with new bottles and $3,000 for a system with used bottles. In either case, these systems are usually purchased and installed as approved fixed fire extinguishing systems and there is little regulatory concern.

For smaller vessels, for example 30 to 45 ft. (9.1 to 13.7 m) fishing boats with the wheelhouse over the engine room, there may be concern. The fixed fire extinguishing system on such vessels may consist of a portable extinguisher located in the wheelhouse with the hose bell removed from the extinguisher and a piece of hose attached. The hose is run through a hole cut in the wheelhouse floor and into the engine compartment. The free end of the hose is suspended from a deck beam above the engine and the bell is attached to the free end. This arrangement is a cheap fixed firefighting system for the vessel owner; however, for a regulator this may be a problem.

The problem from a regulatory perspective is that there is no guarantee that the homemade system will operate as expected. For example, the pipe or hose used may not be suitable for the pressures expected; incorrect pipe size and/or too many bends or kinks in the piping may lead to back pressure, which has an adverse effect on the discharge time and CO_2 concentration in the compartment being flooded. Without the benefit of guidelines regarding the design and fitting of portable extinguisher based fixed CO_2 systems, it is difficult for surveyors to make judgments regarding the safety and effectiveness of these systems.

3. REGULATORY REVIEW

A review was undertaken of national and international regulations, guidelines and standards regarding CO_2 fire extinguishing systems. This review was limited to the following:

1. TP-2237: Equivalent Standards for Fire Protection
2. TP-11717: Standards for the Construction and Inspection of Small Passenger Ships
3. CSA-20: Fire Detection and Extinguishing Equipment Regulations
4. CSA-28: Hull Construction Standards
5. CSA-31: Large Fishing Vessel Inspection Regulations
6. CSA-75: Small Fishing Vessel Inspection Regulations
7. CSA-76: Small Vessel Regulations
8. Construction Standard for Small Commercial Vessels (Draft Report)
9. TP-4813: Fire Protection, Detection and Extinguishing Equipment Regulations (Draft)
10. SOLAS: Safety of Life at Sea, Consolidated Edition, 1992
11. Lloyd's Register: Rules and Regulations for the Classification of Yachts and Small Craft
12. Lloyd's Register: Rules and Regulations for the Classification of Ships
13. Nordic Boat Standard for Commercial Boats Less than 15 Metres, 1990
14. ABYC Standards and Recommended Practices for Small Craft
15. Code of Federal Regulations
16. NFPA-12: Standard on Carbon Dioxide Extinguishing Systems

The relevant information from each regulation is summarized in this section. Most regulations define requirements and provide information on:

- application to vessel type,
- quantity of carbon dioxide,
- storage of cylinders,
- discharge of gas, including percentages of volume, time frames, equipment and shut down requirements,
- instructions and information to be provided to user,
- design of system,
- testing of system, and
- listing or approved equipment.

Only the Code of Federal Regulations and the NFPA-12 standard provide information on pipe sizing and schedules. The NFPA-12 standard also includes specific design requirements as it applies to calculating volume flows and pressure drops within the system. Included within the NFPA-12 annex are examples of designing and calculations for specific installations.

3.1 TP-2237: Equivalent Standards for Fire Protection

These standards apply to passenger ships only. The main regulatory points are:

- Depending on voyage, ships carrying more than 12 passengers require a fixed gas fire extinguishing system in the machinery space of Category 'A'. Where internal combustion machinery (icm) is used for main propulsion or icm used for other purposes has an aggregate total power of not less than 375 kW.
- Where CO_2 is used in the machinery space, quantity shall provide for two discharges of gas equal to at least 40% of the gross volume of the compartment.
- Cargo spaces require a fixed fire extinguishing.
- Wooden, GRP and aluminum ships require two discharges of gas equal to at least 40% of the gross volume of the engine room.

3.2 TP-11717: Standards for the Construction and Inspection of Small Passenger Ships

These standards apply to small passenger ships only. The main regulatory points are:

- Machinery spaces must be protected by a fixed fire extinguishing system.
- System must be manually operated. There is an allowance for automatic discharge in port when propulsion machinery is not operating.
- Wooden, GRP and aluminum ships require two discharges of gas equal to at least 40% of the gross volume of the engine room.

3.3 CSA-20: Fire Detection and Extinguishing Equipment Regulations

These regulations apply to ships under 5 GRT that carry more than 12 passengers, passenger ships over 5 GRT and non-passenger ships over 15 GRT. The main regulatory points are:

- Ships are classed from A thru L depending on type of vessel and voyage.
- Ships (Class A, B, C) registered/licensed before June 1, 1978, which require engine rooms using fuel having a flash point (Pensky-Marten, closed cup) of less than 52°C, require a fixed gas fire extinguishing system delivering not less than 40% of the volume of the compartment.
- Ships (Class A, B, C, G, H) registered/licensed after June 1, 1978, require fixed firefighting systems in engine rooms where internal combustion machinery used for main propulsion is greater than 373 kW.
- Ships (Class A, G, H, K), depending on GRT and whether it is a tank vessel for the carriage of oil products, require cargo spaces, pump rooms, storerooms, lamp rooms, paint lockers and similar compartments to be fitted with a permanent piping system for conveyance of fire smothering gas. Cargo spaces require 30% and all other spaces 40% gas by volume.

Schedule III of CSA-20 details the design requirements for the fixed installations for smothering by foam, gas, steam or water. The main regulatory points for gas smothering systems are:

- Audible warning shall be given when gas is about to be released.

- Systems shall be clearly and permanently marked, indicating the compartment they protect.
- Additional cock or valve shall be fitted in piping for compartments where passengers may have access.
- Provisions for inadvertent discharge of system required.
- Piping, valves and fittings shall have minimum bursting pressure of 41 500 kPa.
- Release system must incorporate stop valve and control valve.
- Operating instructions shall be clearly visible.
- Pressure tests of system shall be conducted.
- Pressure relief valve shall be fitted on cylinder.
- Cylinder shall be stamped, indicating both weight empty and full.
- The gas shall completely discharge within two minutes.
- Adjoining spaces shall be considered one space if free flow of atmosphere between them.
- Storage of cylinders shall be:
    a) suitable for gas contents to be verified,
    b) secured in accessible, dry, well lighted and ventilated position where no risk is posed from leakage,
    c) protected from corrosive elements or temperatures exceeding 54°C
    d) stored in an upright or inverted position with suitable internal solid drawn pipe to maintain separation of liquid and discharge.
- Volume of smothering gas for machinery spaces:
    a) 40% of gross volume including part of the casing,
    b) 35% of gross volume including entire casing,
    c) volume of air receivers shall be additional to volumes calculated above.
- Quantity of liquid carbon dioxide to produce smothering gas shall be on 1 kg of liquid carbon dioxide deemed to produce 0.56 m^3 of gas.

3.4 CSA-22: Hull Construction Standards

Within these regulations, standards applicable to various ships have been identified in ten parts. Parts III, IX and X are relevant to fixed smothering systems. The main regulatory points for gas smothering systems are:

Part III: Fire Protection of Passenger Ships

- Class I, II and specific Class III through VII ships built after March 22, 1967, shall have a fixed smothering system for extinguishing a fire within the exhaust duct from the galley range.
- Baggage and storerooms shall be provided for the smothering of fire by gas.

Part IX: Fire Protection for Tankers and Combination Carriers

- Shall have a fixed smothering system for extinguishing a fire within the exhaust duct from the galley range.
- A fixed gas fire-smothering system shall be provided in each paint locker or similar space.

Part X: Fire Protection for Cargo Ships of 500 Tons Gross Tonnage or more

- Shall have a fixed smothering system for extinguishing a fire within the exhaust duct from the galley range.

- Storage room for medium shall be outside of protected space and shall be accessible from open deck and independent of protected space.
- Paint lockers or similar spaces shall be protected by a fixed gas fire-smothering system.
- Cargo spaces on ships greater than 2000 tons GT shall be protected by a fixed gas fire-smothering system.
- Every space intended for the carriage of vehicles with fuel in their tanks for their own propulsion shall fitted with a fixed fire extinguishing system.

3.5 CSA-201: Large Fishing Vessel Inspection Regulations

These standards apply to new fishing vessels over 24.4 m in length or 150 gross tons. The main regulatory point is:

- Vessels constructed after May 31, 1978, shall be fitted with a carbon dioxide smothering system that discharges into the machinery space.

3.6 CSA-79: Small Fishing Vessel Inspection Regulations

These standards apply to fishing vessels not exceeding 24.4 m in length or 150 gross tons.

- There are no requirements for fixed extinguishing systems.

3.7 CSA-76: Small Vessel Regulations

These standards apply to every vessel that does not exceed 15 tons, register tonnage or, if it is a pleasure craft, does not exceed 20 tons, register tonnage.

- There are no requirements for fixed extinguishing systems.

3.8 Construction Standard for Small Commercial Vessels (Draft)

These standards have been developed for small commercial vessels not exceeding 15 gross tons. The main regulatory point is:

- Spaces protected by a gas smothering system shall be gas-tight such that leakage of the system will not penetrate accommodation and service spaces.

3.9 TP 4913: Fire Protection, Detection and Extinguishing Equipment Regulations

These draft Regulations apply to ships not over 5 gross tons that carry more than 12 passengers, passenger ships over 5 gross tons and non-passenger ships over 15 gross tons with crew. The main regulatory points are:

- Designated Group I and II ships require fixed fire extinguishing systems in way of cargo spaces, Ro/Ro cargo spaces and other cargo spaces with fuelled vehicles.
- Group III ships require fixed fire extinguishing systems in hazardous storerooms and cargo pump rooms.

- Group II ships require fixed fire extinguishing systems in machinery spaces.
- Fixed gas fire-extinguishing systems shall be in accordance with these regulations and the relevant NFPA Standard as applicable with the equipment being approved and listed for marine use by:
    a) Underwriters' Laboratories of Canada,
    b) Underwriters Laboratories Inc., United States,
    c) an approved classification society,
    d) the Department for Transport, United Kingdom, or
    e) other independent test laboratories recognized by Transport Canada.
- Piping, valves and fittings shall be galvanized steel or other approved corrosion resisting material.
- Fire extinguishing medium, which gives off toxic or anesthetic gases, shall not be permitted.
- Protected space adjacent to accommodation or service spaces shall be gas-tight.
- Control valves shall be marked to indicate the spaces to which the pipes are led.
- Control valves shall be quick opening.
- All pipes shall be arranged to be self-draining.
- In carbon dioxide systems the minimum burning pressure of the piping and the fittings in installations using
    a) high pressure gas, shall be 16.5 MPa except that valves containing under pressure shall be 10.5 MPa, and
    b) low pressure gas, shall be 12.5 MPa.
- In systems where the valve arrangement introduces sections of closed piping, such sections shall be protected with automatic pressure relief devices set to relieve at:
    a) between 16.5 MPa and 20.5 MPa, in the case of high pressure systems, and
    b) 3 MPa, in the case of low pressure system.
- Unless ventilation is closed-loop, automatic stopping of ventilation fans serving the protected space is required.
- Where the continuing operation of any machinery or equipment could contribute to sustaining the fire in the hazard or create any other unsafe condition, the source of power or fuel shall be automatically shut off.
- Means shall be provided to close all openings that may admit air to or allow gas to escape from a protected space. Such means shall be automatic where gas release is automatic.
- Clear instructions shall be provided for the operation of the system.
- Automatic release of fire-extinguishing medium shall not be permitted, except as prescribed.
- Manual controls, to secure operation:
    a) shall require a pull not greater than 178 N, and
    b) shall have a travel not greater than 0.356 m.
- Devices shall be normally designed to function from -20°C to 60°C.
- Alarms shall give warning of the release of fire-extinguishing medium into any space in which personnel normally work or have access.
- The alarms shall function to warn against personnel entry into a hazardous space as long as such hazards exist.
- Where the volume of free air is contained in air receivers in any space, additional fire-extinguishing capacity may be required to compensate for the free air equivalent of the pressurized air.

- Where two or more protected spaces are not entirely separate, they shall be considered as forming one space.
- Pressure containers required for the storage of fire-extinguishing medium shall be located outside protected spaces.
- Every fixed pressurized container that is a shipping container shall be constructed, tested and marked in accordance with the requirements of the Canadian Transport Commission.
- Every fixed pressurized container, except where covered in a fire extinguisher that is not a shipping container shall be constructed, tested and marked in accordance with the requirements of
  - a) the American Society of Mechanical Engineers (ASME), Unified Pressure Vessel Code (Section VIII);
  - b) an approved classification society; or
  - c) the British Standards Institute.
- Every pressurized gas container shall be permanently marked to specify the agent, tare and gross weight.
- Except for automatic systems, every fixed pressurized gas container shall be fitted with an automatic pressure relief device venting to a safe location.
- The discharge from carbon dioxide or halon containers shall be monitored from the liquid contents of the containers.
- Means shall be provided to indicate the quantity and pressure of the medium in the container including means to determine if discharged.
- Testing pressures of the system shall be detailed.
- For total flooding systems and local application systems, storage temperatures shall be within a range from −18°C to 50°C and 0°C to 49°C, respectively, unless the system is designed for operation with storage temperatures outside these ranges, external heating or cooling may be used to keep the temperatures within this range.
- High-pressure carbon dioxide supply shall be stored in containers to hold pressurized carbon dioxide in liquid form at atmospheric temperature, corresponding to a nominal pressure of 2.86 MPa (g) at 21°C.
- Release of the carbon dioxide shall be by two separate means, one of which shall be an emergency manual control.
- In machinery spaces, the fire-extinguishing system shall permit the whole charge of gas to be released simultaneously into the space protected.
- In cargo spaces, the arrangements shall be such that the required amount of gas can be supplied from cylinders discharged singly or in groups.
- For cargo spaces, the quantity of medium available shall be sufficient to give a minimum volume of free gas equal to 30% of the gross volume of the largest cargo space so protected in the ship, for special equipment when further small vehicles are carried in the cargo compartment, and in Ro-Ro cargo spaces, see paragraph 37(2) (a), section 38 and section 87 of Part 1.
- For machinery spaces, the quantity of medium carried shall be sufficient to give a minimum volume of free gas equal to the larger of the following volumes, either
  - a) 40% of the gross volume of the largest machinery space so protected, the volume to exclude that part of the casing above the level at which the horizontal area of the casing is 40% or less of the horizontal area of the space concerned taken midway between the tank top and the lowest part of the casing, or
  - b) 35% of the gross volume of the largest machinery space so protected, including

[illegible] [illegible] [illegible] [

- Cargo spaces shall have minimum volume of free gas equal to 30% of the gross volume of the largest cargo space.
- For machinery spaces, the quantity of medium carried shall be sufficient to give a minimum volume of free gas equal to the larger of the following volumes:
  a) 40% of the gross volume of the largest machinery space so protected, the volume to exclude that part of the casing above the level at which the horizontal area of the casing is 40% or less of the horizontal area of the space concerned taken midway between the tank top and the lowest part of the casing; or
  b) 35% of the gross volume of the largest machinery space so protected, including the casing, provided that the above mentioned percentages may be reduced to 35% and 30%, respectively, for Group II ships of less than 2,000 gross tonnage.
- Free carbon dioxide shall be calculated at 0.56 m^3/kg.
- Machinery space discharge shall be >85% within 2 minutes.
- Machinery spaces of Category A containing oil-fired boilers or oil-fuelled units including internal combustion machinery shall be fitted with a fixed fire-extinguishing system.
- Cargo spaces, other than special category spaces, intended for the carriage of fuelled motor vehicles require a fixed fire extinguishing system. If a carbon dioxide system is fitted, the quantity of gas available shall be at least sufficient to give a minimum volume of free gas equal to 45% of the gross volume of the largest such cargo space that is capable of being sealed, and the arrangements shall be such as to ensure that at least two thirds of the gas required for the relevant space shall be introduced during 10 min.
- Ro/Ro spaces shall also comply with the above requirements.

3.11 LR's: Rules and Regulations for the Classification of Yachts and Small Craft

These rules apply to yachts and small craft.

- There are no requirements for fixed extinguishing systems.

3.12 LR's: Rules and Regulations for the Classification of Ships

These internationally recognized rules to all ships. The main regulatory points are:

- Fire extinguishing medium shall not give off toxic gases.
- Control valves shall be clearly marked.
- The discharged medium shall have a uniform distribution.
- Controls shall be located in safe areas.
- Steel pipes fitted in corrosive spaces shall be at least internally galvanized.
- Distribution pipes shall not be smaller than 20 mm bore for carbon dioxide.
- All openings that admit air to or allow gas to escape shall be closable.
- Where the volume of free air is contained in air receivers in any space, additional fire-extinguishing capacity may be required to compensate for the free air equivalent of the pressurized air.
- Automatic alarm system shall give warning of the release of the fire-extinguishing medium.

- Two separate controls shall be provided for the release of carbon dioxide into a space. Each shall activate the alarm.
- One control valve shall be for release of gas from the cylinder and the second from pipeline into protected space.
- Clear operational instructions shall be provided.
- Automatic release shall not be permitted except where noted.
- Pressure containers shall be located outside of protected space.
- Pressure containers shall be to the code of practice recognized by Lloyd's Register.
- Cargo spaces shall have minimum volume of free gas equal to 30% of the gross volume of the largest cargo space.
- For machinery spaces, the quantity of medium carried shall be sufficient to give a minimum volume of free gas equal to the larger of the following volumes:
  a) 40% of the gross volume of the largest machinery space so protected, the volume to exclude that part of the casing above the level at which the horizontal area of the casing is 40% or less of the horizontal area of the space concerned taken midway between the tank top and the lowest part of the casing; or
  b) 35% of the gross volume of the largest machinery space so protected, including the casing, provided that the above mentioned percentages may be reduced to 35% and 30%, respectively, for Group II ships of less than 2,000 gross tonnage.
- Free carbon dioxide shall be calculated at 0.56 m^3/kg.
- Machinery space discharge shall be > 85% within 2 minutes
- Machinery spaces of Category A containing oil-fired boilers or oil-fuelled units including internal combustion machinery shall be fitted with a fixed fire-extinguishing system.
- Cargo spaces, other than special category spaces, intended for the carriage of fuelled motor vehicles require a fixed fire extinguishing system. If a carbon dioxide system is fitted, the quantity of gas available shall be at least sufficient to give a minimum volume of free gas equal to 45% of the gross volume of the largest such cargo space that is capable of being sealed, and the arrangements shall be such as to ensure that at least two thirds of the gas required for the relevant space shall be introduced during 10 min.
- Ro/Ro spaces shall also comply with the above requirements.

3.13 Nordic Boat Standard for Commercial Boats Less than 15 Metres, 1990

The Nordic Boat Standard for Commercial Boats was developed in co-operation among the Maritime administrations in Denmark, Finland, Iceland, Norway and Sweden, and Det Norske Veritas. The main regulatory points are:

- Boats where LOA > 8 m shall have a fixed fire extinguishing system in the engine room.
- Operation of system shall be manual release only.
- Release shall be centrally located outside of protected space.
- Bottles shall be stored outside of engine room.
- Instructions shall be posted at release station.
- Quantity of carbon dioxide shall be 1.5 kg/m^3, with a minimum of 2 kg.
- Half of the volume shall be discharged within 10 seconds.
- Engine rooms shall be gas-tight from spaces for personnel.
- Spaces for bottles shall be ventilated to the open air.

3.14 ABYC: Standards and Recommended Practices for Small Craft

These voluntary technical practices and engineering standards are guides for all boats. The main principle standards are:

- Approved fire extinguishing equipment is required to be carried on motorboats in accordance with U.S. Coast Guard regulations contained in 46 CFR 25. Fixed systems shall be Coast Guard APPROVED or CERTIFIED for marine use.
- Fixed fire extinguishing systems are intended for normally unoccupied spaces. Fixed systems for occupied spaces are not covered by this standard.
- Inboard and Inboard/Outdrive (I/O) boats with engine compartments shall have either:
  a) Fixed fire extinguishing system installed in the machinery space, or
  b) A provision for discharging a suitably sized CO_2 portable fire extinguisher directly into the space.
- Instruction manual shall be provided and contain information about installation, operation, inspection and maintenance of the system.
- Fixed systems shall be one of the following types:
  a) Manual system remotely operated,
  b) Automatic system, or
  c) Automatic/remotely operated manual system.
- Installation of fixed system shall be in accordance with manufacturer's instructions.
- Depending on type of system, placards with specified instructions shall be posted.
- Automatic systems with/without remote manual actuation shall have a remote discharge indicator located at primary helm position.
- Machinery spaces with more than one air change per minute:
  a) shall be able to shut down engines, generators, and blowers automatically;
  b) shall automatically switch to manual only mode when propulsion engines are running;
  c) shall have installed separate fire warning system with indicator at each helm.
- Cylinders shall be accessible for weighing, inspection and removal.
- System shall be raised above deck where water can accumulate.
- System shall have a discharge indicator.
- System must be operational between temperatures of 18°C to 54°C.
- Systems with multiple cylinders shall be specifically engineered.
- For requirements not specified in this standard, NFPA-12 shall apply.
- Design concentrations are determined based on compartment size and flooding factors. Tables are included.
- General maintenance routines are listed for fixed fire extinguishing systems.

3.15 Code of Federal Regulations

The United States government publishes all of its regulations under CFRs. The pertinent sections related to CO_2 systems on board vessels are contained in Code 46. For each vessel type, a complete chapter is designated to provide the reader with complete regulations applicable to that vessel. This tends to make the regulations bulky, but consolidated regulations to particular vessels easily offsets this. The main regulatory requirements are:

Vessels are divided into seven (7) classes as follows:

- Class C: Uninspected Vessels
- Class T: Small Passenger Vessels
- Class R: Nautical Schools
- Class H: Passenger Vessels
- Class U: Oceanographic Vessels
- Class D: Tank Vessels
- Class I: Cargo and Miscellaneous Vessels

3.15.1 Subchapter C: Uninspected Vessels

- The application of this subchapter includes vessels built after September 15, 1991, that carry more than 16 individuals onboard.
- Ships over 79 ft. (24 m) must be fitted with fixed gas fire extinguishing system in the following enclosed spaces containing:
  - Internal combustion engines greater than 50 hp
  - An oil-fired burner
  - An incinerator
  - Gasoline storage
- Pre-engineered systems may only be installed in normally unoccupied machinery spaces, paint locker or space containing flammable liquid stores, gross volume less than 1200 cu. ft. (34 m^3).
- Automatic discharge systems may only be installed in normally unoccupied spaces, gross volume less than 6000 cu. ft. (170 m^3).
- Spaces where gross volume exceeds 6000 cu. ft. (170 m^3) must have a manually actuated and alarmed system.
- System must be approved by Commandant.
- Components must be listed and labelled by nationally recognized testing laboratory.
- Capable of manual actuation from outside of protected space.
- Automatically shut down ventilation systems and reset afterwards.
- Visual alarm at discharge.
- Audible alarm at discharge.

3.15.2 Subchapter T: Small Passenger Vessels (< 100 GRT)

- Fixed carbon dioxide systems shall be installed in:
  a) Machinery and fuel tank spaces where fuel has flashpoint not greater than 110°F (43°C) unless spaces are open to atmosphere.
  b) Paint and oil rooms and similar hazard spaces.
  c) Cargo spaces carrying combustible cargo and inaccessible during voyage.
- Where fixed systems can be supplied by one portable extinguisher the following apply:
  a) Cylinders to be fixed outside of protected space.
  b) Applicator to be fixed so as to discharge into space.
  c) Controls to be accessible.
- The number of pounds of carbon dioxide required for each space protected shall be determined as follows:
  a) For cargo spaces, the number of pounds required shall be equal to the gross

volume of the space in cubic feet divided by a factor of 30.

b) For machinery and fuel tank spaces, paint lockers, oil rooms and similar hazardous spaces, the number of pounds required for each space shall be equal to the gross volume of the space divided by the appropriate factor noted in the following table.

Gross volume of compartment [cu. ft.]		Factor
Over	Not Over	
	500	15
500	1600	16
1600	4500	18
4500		20

c) A separate supply of carbon dioxide need not be provided for each space protected. The total available supply shall be at least sufficient for the space requiring the greatest amount.

- Controls and valves to be located outside of protected space, and accessible.
- Branch lines to be fitted with shut-off valve.
- Stop valve and control valve to be fitted.
- Instructions shall be provided.
- Minimum pipe sizes are as follows:
  a) Branch lines to the various cargo spaces shall be not less than 1/2-in. standard pipe size.
  b) The size of branch lines to machinery and fuel tank spaces, paint lockers, oil rooms and similar hazardous spaces shall be as noted in following table.

Minimum quantity of carbon dioxide required [lb.]	Minimum pipe size [in.]
100	1/4 (Schedule 40)
225	3/4 (Schedule 40)
300	1 (Schedule 80)
600	1-1/4 (Schedule 80)

  c) All piping, valves, and fittings of ferrous materials shall be protected inside and outside against corrosion.
  d) All dead-end lines shall extend at least 2 in. (5.1 cm) beyond the last orifice and shall be closed with cap or plug.
- The total area of all discharge outlets shall not exceed 85% nor be less then 35% of the nominal cylinder outlet area, or the area of the supply pipe, whichever is smaller. The nominal cylinder outlet area in square in. shall be determined by multiplying the factor 0.0022 by the number of pounds of carbon dioxide required except that in no case shall this outlet area be less than 0.110 sq. in. (0.71 cm^2).
- Cylinders shall be upright, readily accessible and, where subject to moisture, at least 2 in. (5.1 cm) above deck.

- Protected spaces shall have means to prevent admission of air.

3.15.3 Subchapter R: Nautical Schools

- All nautical school ships carrying combustible cargo in the holds, between decks, or other closed cargo compartments shall be equipped with inert gas fire-extinguishing system.
- Cabinets, boxes, or casings inclosing manifolds or valves shall be distinctly marked in painted letters about 3 in. (7.6 cm) in height: *CO_2 Fire Apparatus*.
- Pipes for conveying carbon dioxide or other extinguishing vapours for the purpose of extinguishing fire shall not be led into the cabins or other living spaces.
- At annual inspections, all carbon dioxide (CO_2) cylinders shall be examined externally and replaced if excessive corrosion is found; and all cylinders shall also be checked by weighing to determine contents and if found to be more than 10% under required contents of carbon dioxide, the same shall be recharged.
- When a system is fitted in the cargo hold, cargo 'tween-decks, or other closed cargo compartments, or cargo-oil deep tanks, the quantity of carbon dioxide shall be sufficient to give a gas saturation of 30% of the gross volume of the largest cargo hold. The quantity in pounds of carbon dioxide required may be determined approximately by the following formula:

$$W = \frac{LxBxD}{30}$$

where:

W	=	the weight of CO_2 required, in pounds
L	=	the length of the hold, in feet
B	=	the mean breadth of the hold, in feet
D	=	the depth from tank top or flat forming lower boundary to top of uppermost space in which freight may be carried, in feet.

- When system is fitted in the lamp locker, oil room, or like compartments, the quantity in pounds of carbon dioxide determined by dividing the gross volume of the space by a factor of 22. Lamp lockers, oil rooms, and like compartments, in all classes of vessels, shall be wholly and tightly lined with metal. The whole charge of gas shall be released simultaneously by operating one valve and control, and all cylinders shall be discharged in not more than two minutes.
- Pipes used for supplying carbon dioxide to the cargo holds, cargo 'tween-decks, other closed cargo compartments, and cargo-oil deep tanks shall be not less than three-fourths in. inside diameter. Pipes used for supplying carbon dioxide to lamp lockers, oil rooms, and like compartments shall not be less than 1/2 in. inside diameter.
- All valves shall be permanently marked. A space that is normally accessible to crew while the nautical school ship is being navigated shall be fitted with an approved audible alarm in such space, which will be automatically sounded when the carbon dioxide is admitted to the space.
- Prevent the admission of air into the lower parts of cargo holds, cargo 'tween-decks, and other closed cargo compartments while the system is in operation.
- The quantity of carbon dioxide carried shall be sufficient to give a gas saturation of 25% of the gross volume of the largest boiler room from tank top to top of the boilers. Top of

the boilers is to be considered as the top of the shell of a Scotch or leg type of boiler, and the top of the casing or drum, whichever is the higher, on water-tube boilers.

- The quantity of carbon dioxide required may be determined approximately by the following formula:

$$W = \frac{LxBxD}{36}$$

where:

W	=	the weight of CO_2 required, in pounds
L	=	the length of the boiler room, in feet
B	=	the breadth of the boiler room, in feet
D	=	the distance from tank top or flat forming lower boundary to top of boilers, in feet.

- When a carbon dioxide (CO_2) smothering system is fitted in the machinery space of a nautical school ship propelled by internal combustion engines, the quantity of carbon dioxide required may be determined approximately by the following formula:

$$W = \frac{LxBxD}{22}$$

where:

W	=	the weight of CO_2 required, in pounds
L	=	the length of machinery space, in feet
B	=	breadth of the machinery space, in feet
D	=	distance from tank top or flat forming lower boundary to the underside of deck forming the batch opening, in feet.

- The whole charge of gas shall be capable of being released simultaneously by operating one valve and control. Complete discharge in not more than two minutes. Uniform distribution over the entire area protected. An alarm that shall operate automatically to give a warning in the space when the carbon dioxide is about to be released. Prevent the admission of air into the lower parts of the boiler or engine room while the system is in operation.

3.15.4 Subchapter H: Passenger Vessels

- The following spaces require fixed carbon dioxide extinguishing systems:
  1. Paint and lamp rooms
  2. Inaccessible baggage, mail, and special rooms and storerooms
  3. Oil-fired boilers: Spaces containing oil-fired boilers either main or auxiliary, their fuel oil service pumps, and/or such other fuel oil units as the heaters, strainers, valves, manifolds, etc., that are subject to the discharge pressure of the fuel oil service pumps, together with adjacent spaces to which the oil can drain
  4. Internal combustion or gas turbine propelling machinery spaces
  5. Enclosed ventilating systems for motors and generators of electric propelling machinery
  6. Cargo spaces inaccessible during voyage (combustible cargo), including trunks (excluding tanks)

7. Cargo oil tank (carbon dioxide or foam)
8. Cargo spaces specially suitable for vehicles

- Approved fire extinguishing shall be installed, as required above on the following vessels:
  a) All self-propelled vessels.
  b) After July 1, 1957, all barges with sleeping accommodations for more than six persons.
- A separate supply of carbon dioxide need not be provided for each space protected. The total available supply shall be at least sufficient for the space requiring the greatest amount.
- The number of pounds of carbon dioxide required for each cargo space shall be equal to the gross volume of the space in cubic feet divided by 30.
- Branch lines to the various cargo holds and 'tween-decks shall not be less than 3/4-in. standard pipe size. No specific discharge rate need be applied to such systems.
- Enclosed ventilation systems for rotating electrical propulsion equipment. The number of pounds of carbon dioxide required for the initial charge shall be equal to the gross volume of the system divided by 10 for systems having a volume of less than 2000 cu. ft. (56.6 m^3), and divided by 12 for systems having a volume of 2000 cu. ft. (56.6 m^3) or more. Discharge of the required amount shall be completed within 2 minutes. Sufficient carbon dioxide available to permit delayed discharges to maintain at least a 25% concentration until the equipment can be stopped. The piping for the delayed discharge shall not be less than 1/2-in. standard pipe, and no specific discharge rate need be applied to such systems. On small systems, this pipe may be incorporated with the initial discharge piping.
- Machinery spaces, paint lockers, and similar spaces. The number of pounds of carbon dioxide required for each space shall be equal to the gross volume of the space divided by the appropriate factor noted in the following table.

Gross volume of compartment [cu. ft.]		Factor
Over	Not Over	
	500	15
500	1600	16
1600	4500	18
4500	50000	20
50000		22

- Branch lines in the various spaces shall be noted in the following table.

Maximum quantity of carbon dioxide required [lb.]	Minimum pipe size [in.]
100	1/2
225	3/4
300	1
600	1-1/4

1000	1-1/2
2450	2
2500	2-1/2
4450	3
7100	3-1/2
10450	4
15000	4-1/2

- Uniform distribution throughout the space.
- The total area of all discharge outlets shall not exceed 85% nor be less than 35% of the nominal cylinder outlet area or the area of the supply pipe, whichever is smaller. The nominal cylinder outlet area in square in. shall be determined by multiplying the factor 0.0022 by the number of pounds of carbon dioxide required, except that in no case shall this outlet area be less than 0.110 sq. in (0.71 cm^2).
- The discharge of at least 85% of the required amount of carbon dioxide shall be complete within 2 minutes.
- Spaces especially suitable for vehicles. The number of pounds of carbon dioxide required shall be equal to the gross volume of the largest "tight" space divided by 22. In no case, however, shall it be less than that required by #4. The discharge of the required quantity of carbon dioxide shall be completed within 2 minutes.
- All controls and valves for the operation of the system shall be outside the space protected.
- Distribution piping to the dry cargo spaces shall be controlled from not more than two stations. One of the stations controlling the system for the main machinery space shall be located as convenient as practicable to one of the main-escapes from the space.
- Systems shall be actuated at each station by one control operating the valve to the space and a separate control releasing the required amount of carbon dioxide. Systems installed without a stop valve shall be operated by one control releasing the required amount of carbon dioxide.
- Where provisions are made for the simultaneous release by operation of a remote control, provisions shall also be made for manual control at the cylinders.
- Systems for spaces as described in #7 and which are of more than 300 lb. (136 kg) of carbon dioxide shall be fitted with an approved delayed discharge so arranged that an alarm will be sounded for at least 20 seconds before the carbon dioxide is released. Such systems of not more than 300 lb. (136 kg) of carbon dioxide shall also have a similar delayed discharge, except for spaces, which have a suitable horizontal escape.
- All distribution valves and controls shall be of an approved type.
- Complete but simple instructions for the operation of the systems.
- The piping, valves, and fittings shall have a bursting pressure of not less than 6000 psi (41 MPa).
- All piping, in nominal sizes not over 3/4-in. shall be at least Schedule 40 (standard weight) and in nominal sizes over 3/4-in., shall be at least Schedule 80 (extra heavy).
- All piping, valves, and fittings of ferrous materials shall be protected inside and outside against corrosion.

- A pressure relief valve or equivalent set to relieve between 2400 and 2900 psi (16.5 and 19 MPa). Shall be installed in the distributing manifold or such other location as to protect the piping in the event that all branch line shut- off valves are closed.
- All dead-end lines shall extend at least 2 in. (5 cm) beyond the last orifice.
- Installation test requirements are:
  a) The piping from the cylinders to the stop valves in the manifold shall be subjected to a pressure of 1000 psi (6.89 MPa). Allowable pressure drop of more than 150 psi (1 MPa) per minute for 2 minute period.
  b) The individual branch lines shall be pressure tested at 600 psi (4 MPa).
  c) Small independent systems may be tested by blowing out the piping with air at a pressure of at least 100 psi (0.69 MPa).
- The cylinders shall be located outside the spaces protected.
- Systems consisting of not more than 300 lb. (136 kg) of carbon dioxide, may have the cylinders located within the space protected. If the cylinder stowage is within the space protected, the system shall be arranged in an approved manner to be automatically operated by a heat actuator within the space in addition to the regular remote and local controls.
- The space containing the cylinders shall be properly ventilated with an ambient temperature less than 130°F (54°C).
- Cylinders shall be readily accessible.
- Where subject to moisture, cylinders shall be so installed at least 2 in. (5 cm) above deck.
- Cylinders shall be mounted in an upright position.
- All cylinders used for storing carbon dioxide must be fabricated, tested, and marked.
- Discharge outlets shall be of an approved type.
- Spaces that are protected and are normally accessible to persons on board while the vessel is being navigated, other than paint and lamp lockers and similar small spaces shall be fitted with an approved audible alarm, which will be automatically sounded before the carbon dioxide is admitted to the space. For systems installed on or after July 1, 1987, alarms will be mandatory only for systems required to be fitted with a delayed discharge. Such alarms shall be so arranged as to sound during the 20-second delay period.
- Where mechanical ventilation is provided for spaces other than cargo and similar spaces, provisions shall be made so that the ventilation system can be automatically shut down.
- Where natural ventilation is provided, provisions shall be made for easily and effectively closing off the ventilation.
- Where necessary, relatively tight compartments shall be provided with suitable means for relieving excessive pressure when the carbon dioxide is injected.
- Installations contracted for prior to November 19, 1962, have the following requirements:
  a) In boiler rooms, the number of pounds of carbon dioxide shall be equal to the gross volume divided by 36.
  b) In machinery spaces where main propulsion internal combustion machinery is installed, the number of pounds of carbon dioxide required shall be equal to the gross divided by 22.
  c) In miscellaneous spaces other than cargo or main machinery spaces, the number of pounds of carbon dioxide required shall be equal to the gross volume of the space divided by 22.
  d) Branch lines to the various spaces other than cargo and similar spaces shall be as noted in the following table. This table is based on cylinders having discharge

outlets and siphon tubes of 3/8-in. diameter.

Number of Cylinders		Nominal Pipe Size [in.]
Over	Not Over	
	2	1/2 standard
2	4	3/4 standard
4	6	1 extra heavy
6	12	1-1/4 extra heavy
12	18	1-1/2 extra heavy
18	27	2 extra heavy
27	39	2-1/2 extra heavy
39	63	3 extra heavy
63	81	3-1/2 extra heavy
81	104	4 extra heavy
104	162	5 extra heavy

5.15.5 *Subchapter U: Oceanographic Vessels*

- The following spaces require fixed carbon dioxide extinguishing systems:
  1. Paint and Lamp rooms.
  2. Enclosed spaces containing gasoline engines.
  3. Oil fired boilers: Spaces containing oil fired boilers either main or auxiliary, their fuel oil service pumps, and/or such other fuel oil units as the heaters, strainers, valves, manifolds, etc.
  4. Vessels over 1000 gross tons, Internal combustion or gas turbine propelling machinery spaces over 1000 bhp (746 kW).
  5. Chemical storerooms.
  6. Enclosed ventilating systems for motors and generators of electric propelling machinery.
- The requirements are as per Subchapter H Passenger Vessels, except for the following Nos.: 2, 4, 5, and 12.
- Requirement 38 should read Installation contracted prior to March 1, 1968.

5.15.6 *Subchapter D: Tank Vessels*

- The following spaces require fixed carbon dioxide extinguishing systems:
  1. Dry cargo compartments.
  2. Cargo tanks. A deck foam system shall be installed for the protection of all cargo tank spaces. Where a deck foam system is installed, an approved inert gas, steam or other system may also be installed for purposes of fire prevention or purging of cargo tanks. On vessels contracted for prior to January 1, 1962, a steam smothering inert gas, fixed foam or carbon dioxide system may be used in lieu of the deck foam system for the protection of the cargo tank spaces.
  3. Lamp and paint lockers and similar spaces.
  4. Pump rooms.

5 Oil fired boilers: Spaces containing oil fired boilers other than auxiliary, fuel oil service pumps, and/or each other fuel oil units as the heaters, strainers, valves, manifolds, etc.

6 Machinery spaces containing internal combustion propelling engines using fuel having a flashpoint of less than 110°F (60°C).

7 Vessels over 1000 gross tons, Internal combustion or gas turbine propelling machinery spaces over 1000 bhp (746 kW).

8 Enclosed ventilating systems for motors and generators of electric propelling machinery.

- The requirements are as per Subchapter H Passenger Vessels, except for the following Nos.: 2, 6, 7 and 12.
- Requirement 4 should read "The number of pounds of carbon dioxide required for each dry cargo space shall be equal to the gross volume of the space in cubic feet divided by 30".
- Requirement 7 should read "Machinery spaces, pump rooms, paint lockers, and similar spaces. The number of pounds of carbon dioxide required for each space shall be equal to the gross volume of the space divided by the appropriate factor noted in the following table".
- Requirement 10 should read Installation contracted prior to January 1, 1962.

5.15.7 *Subchapter I: Cargo and Miscellaneous Vessels*

- The following spaces require fixed carbon dioxide extinguishing systems:
  1 Cargo compartments and tanks for combustible cargo except for coal and grain.
  2 Cargo spaces especially suitable for vehicles.
  3 Lamp and paint lockers and similar spaces.
  4 Pump rooms.
  5 Vessels over 1000 gross tons, Spaces containing oil fired boilers other than auxiliary, fuel fuel oil service pumps, and/or each other fuel oil units as the heaters, strainers, valves, manifolds, etc.
  6 Machinery spaces containing internal combustion propelling engines using fuel having a flashpoint of less than 110°F (60°C).
  7 Vessels over 1000 gross tons, Internal combustion or gas turbine propelling machinery spaces over 1000 bhp (746 kW).
  8 Enclosed ventilating systems for motors and generators of electric propelling machinery.
- The requirements are as per Subchapter H Passenger Vessels, except for No. 2.

5.16 NFPA 12: Standard on Carbon Dioxide Extinguishing Systems

The standard contains the minimum requirements for carbon dioxide fire extinguishing systems as determined by the National Fire Protection Association. The following main requirements and descriptions are noted:

- The requirements of the CO2 systems for small vessels generally falls under the Total Flooding system described as a system consisting of a supply of carbon dioxide arranged

to discharge area, and (b) in the proper concentration, as indicated prior to entrance there-to/be-issued.

- Suitable personnel safeguards shall be provided to ensure prompt evacuation and prevent entry into hazardous atmosphere.
- Appropriate warning signs shall be posted.
- The following details should be provided for approval:
  - a) Information and calculations on the amount of CO_2,
  - b) Location and flow rate of each nozzle including equivalent orifice area,
  - c) Location, size and equivalent length of pipe, fittings and hose,
  - d) Location and size of CO_2 storage facility, and
  - e) Details of pipe size reduction method and orientation of tee.
- Instruction and maintenance manual shall be maintained.
- Only listed and approved equipment and devices shall be used in the system.
- Details of detection, actuation and control as provided within the standard.
- Devices shall be designed to function from –20°C to 60°C.
- Ambient storage temperature for Total Flooding systems shall be within –18°C to 50°C.
- Manual controls shall be of distinctive appearance and clearly recognizable.
- Manual controls shall not require more than 178 N to a maximum of more than 356 mm.
- Where the continuing operation of equipment could contribute to sustaining a fire, the source of power to fuel shall be automatically shut off.
- Pre-discharge alarms shall be provided.
- An alarm or indicator shall be provided to show that the system has operated and needs recharging.
- Both main and reserve m_2 (–) or fixed storage systems shall be permanently connected to the piping.
- Storage containers and accessories shall be located as near as to the hazard and arranged to facilitate inspection, maintenance and recharging.
- Venting of cylinders is specifically provided within the standard.
- Safety relief valve required on cylinders.
- Piping shall be non-combustible and valves installed to prevent corrosive atmosphere shall be made of non-corrosive material or coatings shall be used.
- Black or galvanized steel pipe shall be ASTM A 53 seamless or electrically welded Grade A or B or ASTM A 106 Grade A, B or C. ASTM A 120 and ordinary pipe shall not be used. Specific requirements for stainless steel are also detailed within the standard.
- High pressure systems using 21 m. and smaller pipe may be threaded. Sch. 160 through 6 in. shall be a minimum of Schedule 80.
- Piping system components not specifically covered shall have minimum bursting pressure of 68.97 kPa.
- Class 150 and cast iron fittings shall not be used.
- High pressure fittings shall be Class 300 malleable or ductile iron fittings up to 5 in. Flanged joint dimensions of any valve shall be Class 600. Flanged joint dimensions of any valve or in systems with no any valve may be Class 300.
- Piping in high pressure systems shall have a minimum bursting pressure of 68.97 kPa.
- General construction details for systems are detailed within the standard.
- Systems with sections of closed piping shall have pressure relief valves within these sections. Operation of between 68.97 kPa and 20 684 kPa in high pressure systems.

- Valves for high-pressure systems shall have a minimum bursting pressure of 1.5 times the rated pressure and a working pressure of 1.2 times the rated pressure.
- Bushings must be lubricated.
- Bushings must be corrosion resistant.
- Pipe sizes and orifice sizes shall be selected based on calculations to deliver the required air at least as much. The manufacturer provides examples and methodology for calculations.
- Minimum maintenance schedules and procedures are listed in recommendations within the manual.
- Load bleeding systems are provided within the manual.
- Calculations for volume of water should required to monitor a vessel so that it volume of moisture and a bleeding space. The following table presents the bleeding space used.

Volume of Space	Volume Drain	Calculated Quantity Bag
$(x^{2}\cdot 9x)$	$(x^{2}\cdot 9x)$	Quantity
$(x+6,\ 3)$	$(x+6,\ 3)$	$(x+6,\ 3)$
$(x+6,\ 3)$	$(x+6,\ 3)$	$(x+6,\ 3)$
$(x+6,\ 3)$	$(x+6,\ 3)$	$(x+6,\ 3)$
$(x+6,\ 3)$	$(x+6,\ 3)$	$(x+6,\ 3)$
$(x+6,\ 3)$	$(x+6,\ 3)$	$(x+6,\ 3)$
$(x+6,\ 3)$	$(x+6,\ 3)$	$(x+6,\ 3)$

- A maximum discharge rate is not defined within the standard however a minimum discharge rate is set at 20 seconds.
- For any high-pressure testing may be required and this is defined within the standard.
- System discharge rate is recommended to be equal to 0.5kg/minute.
- Recompressed systems may differ from those standard as they are designed for specific vessels.

4. VESSEL SURVEYS

Eleven vessels were surveyed to obtain an understanding of the arrangement and components used in portable extinguisher based CO_2 fixed firefighting systems fitted onboard Canadian small vessels. This section discusses the vessels surveyed and pertinent findings.

4.1 Surveys Completed

Eleven vessels surveys were completed as noted below:

- Pacific Region - 1 vessel in the Victoria, British Columbia,
- Laurentian Region - 5 vessels in Magdelene Islands, and
- Maritimes Region - 5 vessels in Nova Scotia.

As some owners/operators requested that the surveys be kept confidential, completed survey forms are not presented and vessels are simply identified as A, B, C etc. Table 4.1 provides a summary description of the vessels surveyed. Table 4.2 provides a summary of the portable extinguisher based CO_2 fixed firefighting systems installed onboard these vessels.

Table 4.1
Vessels Surveyed

ID	L [m]	B [m]	GRT [tonnes]	Power [kW]	Vessel Type	Location
A	12.8	4.9	14.87	175	Tour Boat	Maritimes
B	13.7	5.18	28	231	Dive Boat	Maritimes
C	12.8	4.9	9.8	89	Tour Boat	Maritimes
D	12.8	4.3	11	?	Fishing/Tour Boat	Maritimes
E	12.4	5	11	177	Fishing Vessel	Laurentian
F	12.1	4.6	13	160	Fishing Vessel	Laurentian
G	10.8	5	14	154	Fishing Vessel	Laurentian
H	11.5	4.6	15	155	Fishing Vessel	Laurentian
I	11.8	4.9	11.6	168	Fishing Vessel	Laurentian
J	12.8	3.7	26	157	Fishing/Research Vessel	Pacific
Vessel surveys completed between February and March 1998						

Table 4.2
System Descriptions on Vessels Surveyed

Vessel	Approx. E/R Vol.	Bottles [lb.]	Piping	Diffusers	Alarm Systems	Approx. Cost [$ Cdn.]
A	?	2 x 20	3/8 in. hose to 1/2 in. galvanized pipe (Sch. 40)	2 of (1 per bottle)	none	480
B	?	1 x 20	3/8 in. hydraulic hose	1 of	none	180
C	15 m³	2 x 20	3/8 in. hose to 1/2 in. copper tube	2 of (1 per bottle)	none	400
D	?	2 x 20	1/2 in. copper tubing (soldered) to common tubing	1 of (manifolded)	none	550
E	12 m³	4 x 25	synthetic hose to 1/2 in. galvanized pipe	4 of (1 per bottle)	none	500 - 600
F	12 m³	2 x 20	1/2 in. and 3/4 in. galvanized pipe, screwed fittings	1 x 4 in. (manifolded)	none	600 - 700
G	13 m³	1 x 12, 1 x 20	synthetic hose to 3/4 in. galvanized pipe	2 x 2 in. (1 per bottle)	none	600
H	12 m³	2 x 25	1/2 in. galvanized pipe to 3/4 in. galvanized pipe	1 x 3 1/2 in. (manifolded)	none	650
I	13.5 m³	2 x 20	1/2 in. synthetic hose to 3/4 in. galvanized pipe	2 x 2 in. (manifolded)	heat and smoke	650
J	6.3 m³	1 x 15	1/2 in. copper tube and 1/2 in. flexible copper tube	1 x 2 in.	heat	

Notes:
[A] Primary system for this vessel is a 17 lb. Halon 1301, CO_2 system is owner installed backup
[C] Primary system for this vessel is an automatic Halon system, CO_2 system noted above is back-up
[F] Systems serves engine room (3 bottles) and battery compartment (1 bottle)
[G] System noted is a fairly new installation, back-up consists of 1 x 2 3/4 lb. and 1 x 5 lb. portable extinguishers
[H] back-up consists of 1 x 2 3/4 lb. and 1 x 5 lb. portable extinguishers
[J] Back-up consists of 2 x 2 3/4 lb. and 2 x 1 lb. portable extinguishers
[K] Back-up consists of 2 x 5 lb. portable extinguishers

4.2 Survey Findings

Summary descriptions of the CO_2 systems surveyed are presented in Table 4.2. The general findings and observations are listed below:

- Generally, there are two common arrangements for portable extinguisher based CO_2 fixed firefighting systems on small vessels:
  - [i] independent distribution, or
  - [ii] manifolded distribution.

- The basic components of each arrangement are as follows:
  - mounting brackets for bottle
  - high-pressure bottle
  - control head
  - piping and/or hose
  - pipe and/or hose fittings
  - diffuser

- In the systems surveyed, the combination of a high-pressure bottle and control head is provided by a portable extinguisher. Materials used for piping are usually copper tube, galvanized steel pipe and hydraulic hose; a single system may include a combination of these materials. Fittings used are typically limited to elbows, tees, in-line connectors and adaptors (i.e. 3/4 in. to 1/2 in.).

- Seven of the systems surveyed involved separate distribution systems. That is, single bottles attached to an independent piping system supplying a single diffuser. The other four systems were manifolded with bottles feeding a common piping system supplying one or more diffusers.

- The majority of systems surveyed utilised the bell diffusers from the portable extinguishers. These were removed from the hose supplied with the extinguisher and re-connected at the end of a piping run.

- All systems were manual release; the operator is required to pull a pin and squeeze the handle until the bottle is completely discharged.

- Very few of the bottles were equipped with gauges indicating the bottle pressure.

- Only two of the vessels surveyed were fitted with smoke and/or heat detectors in the engine room. This was sighted as a concern since the engine rooms on these vessels are small and enclosed; access via a hatch of covered doorway. It could be several minutes before a fire was detected.

- None of the installations surveyed were equipped with automatic fire detection and gas discharge. CO_2 discharge into the engine room could inadvertently shut down the engine; this would be of particular concern if the vessel were operating in tight quarters.

- Very few of the systems surveyed were properly signed or labelled as being protected by a carbon dioxide system. Furthermore, operating instructions were not posted.

- Not all cylinders come supplied with proper mounting brackets. Various means of securing cylinders were noted; wood brackets, boxes, fabricated straps etc.

- In some instances, it was noted that access to the cylinders was hampered. Some installations surveyed were completely enclosed requiring the removal of a cover in order to gain access. Furthermore, in some cases fishing gear, rain gear and/or lifesaving equipment was observed piled on top of the cylinders.

- Location of cylinders varied from vessel to vessel, some were located inside the wheelhouse while others were outside adjacent to the cabin on the main deck. Cylinders not located inside the wheelhouse/cabin are prone to excessive corrosion. In particular, the valve pin can become seized which renders the cylinder inoperable.

- In some cases, there was concern over the quantity of gas in the system. Owners calculate the volume of the engine room by measuring length, width and height and then size cylinders for a 40% concentration of CO_2. This is a logical approach, however, in small vessels there is often no bulkhead in the keel. Consequently, gas discharged into the engine room compartment would escape to the keel and travel the full length of the vessel thus diluting the gas concentration in the engine room. Furthermore, the air tightness of bulkheads in small vessel engine rooms is typically suspect.

- Small vessels equipped with portable extinguisher based fixed CO_2 systems do not always operate in calm seas. Often they are at sea when seas are running high and stable footing can be a problem. With standard portable extinguisher heads fitted, in the event of fire an operator would be required to access the cylinders, pull the pins and squeeze the lever until the contents are completely discharged. A lone operator may be required to leave the wheel to perform this task.

- The use of copper tubing (household M grade) and soldered connections is of some concern. Typical bottle pressure is around 850 psi at 70°F (5860 kPa at 21°C). Rated internal working pressure for Drawn M grade copper tubing at 100°F (38°C) is 855, 741 and 611 psi (5895, 5109, 4212 MPa) for 3/8 in., 1/2 in. and 3/4 in. size respectively. For 1/4 to 1 in. size at 100°F (38°C), the recommended maximum internal working pressure for type M joints soldered with 95/5 Tin-Antimony solder is 635 psi (4378 kPa) [3].

- For the vessel types surveyed (fishing boats and tour boats), inspection requirements are somewhat erratic as passenger carrying vessels have a yearly inspection interval while the inspection interval for fishing boats over 15 tons is every four years. Cylinders returned for service and inspection are treated as portable fire extinguishers and hydrostatically tested every five years.

5. VESSEL STATISTICS

This section provides an estimate on the number of small vessels in Canada that have homemade fixed firefighting systems, similar to those surveyed in the previous section, installed. Data estimating the number of small vessels in Canada permits general qualitative commentary on the installed power on these vessels and engine room volume.

5.1 Licensed Vessels

Transport Canada keeps statistics on small vessels *licensed* in Canada. The number of licensed vessels in Canada (as of 31 December 1997) is noted by geographic region in Table 5.1 [4].

Table 5.1
Vessels Licensed in Canada

Region	# Licences Issued
Newfoundland	45 482
Prince Edward Island	8920
Nova Scotia	52 179
New Brunswick	38 702
Quebec	284 907
Ontario	953 296
Manitoba	81 377
Saskatchewan	78 132
Alberta	112 557
British Columbia	310 004
Yukon Territory	3616
Northwest Territories	1670
Total	**1 970 842**

Licensed vessels do not exceed 15 Gross Registered Tonnage (20 GRT if a pleasure craft) and are equipped permanently or temporarily with a propulsion power of 7.5 kW or more [5]. The vessels represented by these numbers cover a wide range of vessel types including personal watercraft, dinghies, recreational powerboats and commercial fishing vessels. Transport Canada personnel estimate that about 4% to 5% of the total number of licensed vessels are small commercial boats: ~ 65 000 commercial workboats and ~30 000 commercial fishing boats.

5.2 Registered Vessels

Vessels *registered* in Canada appear in the "List of Ships" produced by Transport Canada. This database identifies 31 365 vessels registered in Canada 15 GRT and less [6]. This distribution of these vessels by vessel type is noted in Table 5.2. It should be noted that the majority of these vessels are fishing vessels.

Table 5.2
Vessels Registered in Canada

# of Vessels =	360	1367	1438	1548	1696	1825	2066	2375	2454	2723	2681	3038	2672	2772	2354	31365
Vessel	Gross Registered Tonnage															# Vessels
Type	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	by Type
Barge - Accomodation																
Barge - Cargo													1	1		2
Barge - Crane/Derrick							1								1	2
Barge - Diving								1					3			4
Barge - Dump															1	1
Barge - Gas																
Barge - Grain Elevator																
Barge - Oil Tank																
Barge - Oil Tank / Cargo																
Barge - Other		2	2	5	4	22	12	4	4	4	11	7	9	10	5	101
Barge - Passenger / Vehicle																
Barge - Pile Driver / Construction								2								2
Bulk Carrier																
Buoy Tender/Re-Supply																
Cable Ship																
Conical Drilling Unit																
Crew Boat					1											1
Dredge		1			2		1	3		1		1	2	2	1	14
Ferry - Cable																
Ferry - Other		1								1		1	1	1		5
Ferry - Passenger		2	1	5	5					2	1			6		22
Ferry - Passenger/Vehicle/Train																
Ferry - Passenger/Train																
Ferry - Passenger/Vehicle																
Ferry - Train																
Ferry - Vehicle																
Fire Fighting										4						4
Fish Factory																
Fishing - Other	290	310	625	680	701	731	739	1010	1101	1458	1508	1917	1842	1964	1643	18619
Fishing Protection						1				2	2	1		1	1	8
Fishing Research														1		1
Floating Dry Dock																
General Cargo		1		6	19		3	13	2		6	6	5	8	9	78
Grimel							1	6	6	5	5	3	1	1	1	29
Harbour Tug			1							2		1	2	6	2	14
Hospital/Medical Service										1						1
Houseboat												1	1	1	1	4
Hydrographic Survey		1														1
Icebreaker																
Landing Craft																
Lifeboat Search and Rescue					1				1		1					3
Longliner													1	5		6
Museum																
Non-Commercial - Other		2	2	4	8	8	7	4	10	14	7	6	11	5	5	91
Oceanic/Hydrographic Survey																
Oceaographic Survey									1							1
Offshore - Other																
Oil Drill Ship																
Oil Rig - Jackup																
Ore/Bulk/Oil Ship																
Packer Bait/Transfer									2	3			1		3	9
Passenger		9	20	40	81	7	4	11	9	12	5	16	12	7	15	248
Passenger - Cargo															1	1
Passenger - Container																
Patrol Boat				2	3		2	7	2	8	2	3	2	8	2	41
Pilot Boat			1						1					4	4	10
Pollution Protection																
Production Platform																
Rescue Standby Ship																
Research/Survey - Other	5		4	1	4	1	4	3	2	4	3	8	3	5	7	54
RORO - Roll - On, Roll - Off Ship																
Salvage Tug	2	7	11	2	7	2	6	8	8	6	2	3	1	1	4	70
Sealer																
Seiner												1			1	2
Seismic Research																
Ships - Other																
Special - Other																
Submersible						1										1
Supply/Anchor Handling Ship								1								1
Tanker - Product													1			1
Trashing																
Trawler / Dragger								1				1		2	2	6
Troller					2	2	5	6	5	3	9	8	6	10	9	65
Tug - Other	42	806	436	254	149	69	66	58	106	148	49	41	29	69	76	2398
Whaling																
Workboat/Tender Tug	5	98	98	121	131	15	34	34	44	28	12	20	19	25	31	715
Yacht	16	127	237	426	578	968	1181	1203	1150	1017	958	993	719	627	529	10729

5.3 Analysis of Results

Summarising the statistics presented in the previous two sub-sections it may be stated that there are approximately 31 365 *registered* and 1 970 842 *licensed* vessels in Canada less than 15 GRT. Although there is some possibility of recreational craft using small ULC approved fixed system, commercial vessels are the most likely to consider fixed system installation. Therefore, to be both realistic and conservative only commercial vessels are considered further:

- Approx. 30 000 *licensed* and 16 600 *registered* fishing boats.
- Approx. 65 000 *licensed* and over 1000 *registered* workboats.

Summing these numbers yields 112 600 commercial small vessels in Canada. Estimating the number of vessels that either are equipped with a fixed CO_2 fire extinguishing is impossible without extensive survey work. The same is true of estimating what percentage of these systems would be low volume systems.

Data on engine room volume vs. GRT is not readily available. However, data on installed power vs. GRT may be derived from the *registered* ships database. Figure 5.1 shows installed power vs. GRT for a random sampling of this database (300 records).

Figure 5.1
Raw Data: Installed Power vs. GRT

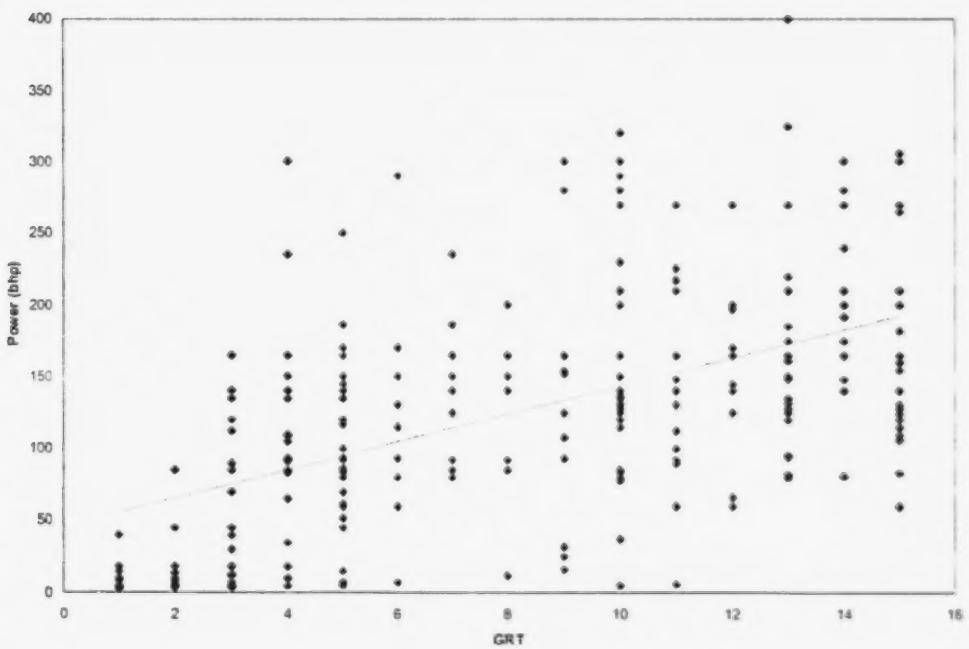
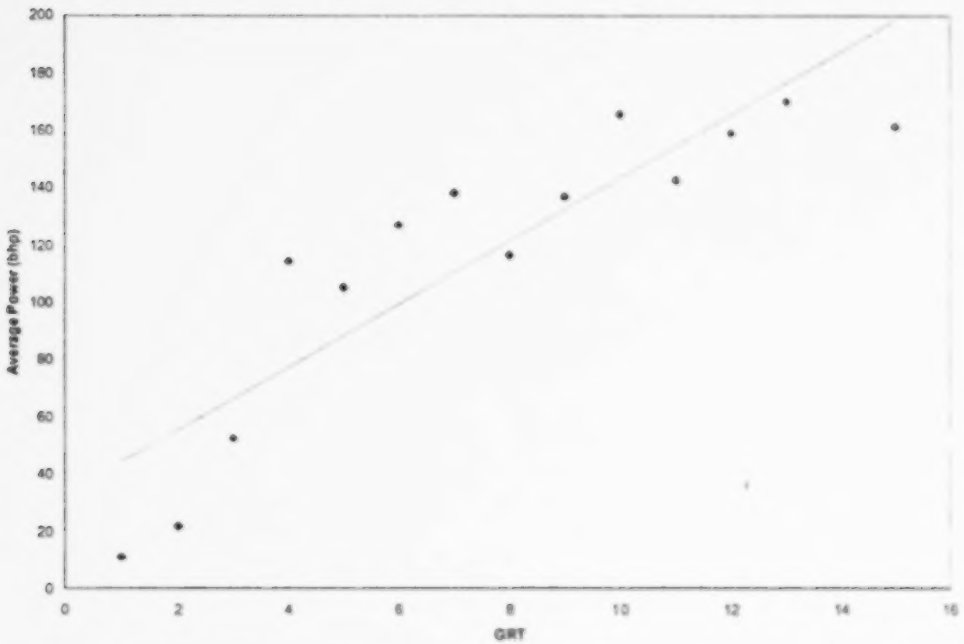


Figure 5.1 shows a large degree of scatter. This is the result of a number of factors including vessel age, vessel arrangements and fisheries type. In order to draw some general conclusions, the data presented in Figure 5.1 was conditioned by calculating the average power for each GRT. The results are shown in Figure 5.2.

Figure 5.2
Conditioned Data: Installed Power vs. GRT

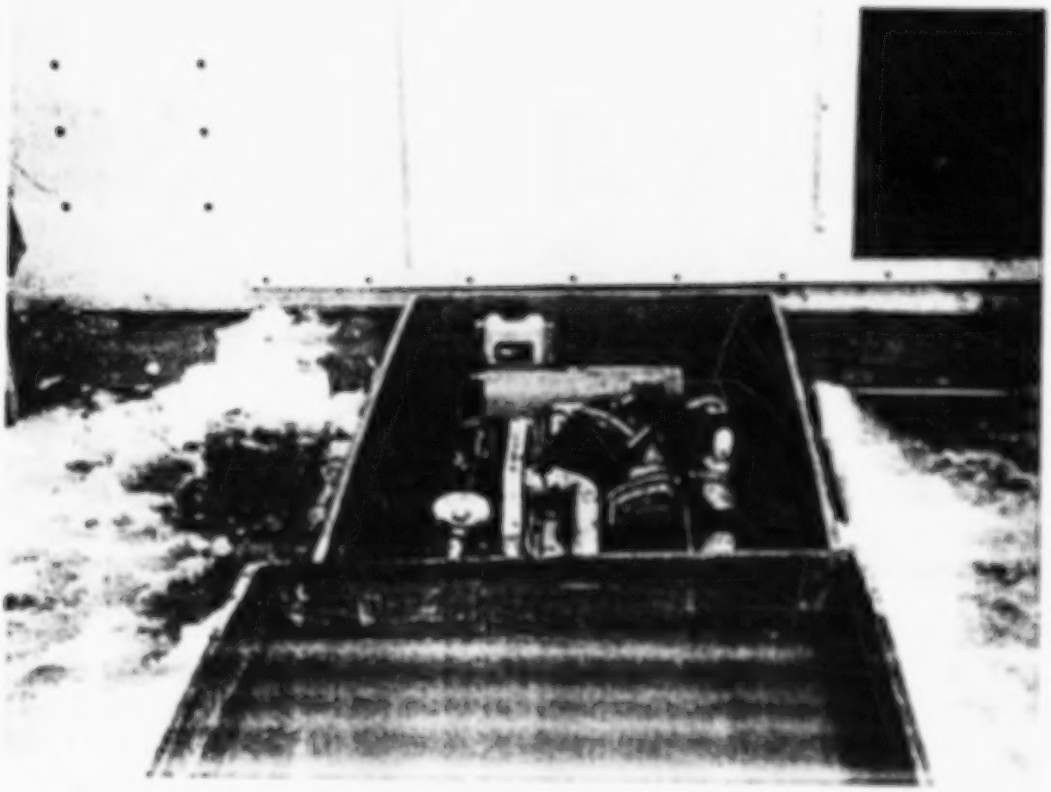


Generalizing, we may consider vessels under 4 GRT to have an installed power of less than 80 bhp (60 kW). In many instances, this powering will be provided by outboard engines and will not require fixed extinguishing systems. For vessels between 4 and 15 GRT (length between 20 and 45 ft. or 51 and 114 m), average installed power lies between 100 and 200 bhp (74.6 and 149 kW); this represents approximately 90% of all *registered* fishing vessels under 15 GRT. These vessels are of particular interest to this study.

The vessels noted above are characterized by small engine compartments. This is particularly true of fishing vessels where volume is at a premium as it is used for cargo hold volume (i.e. fish). A common engine space arrangement is that of an under deck compartment whose dimensions are typically no larger than 25% greater length, breadth and depth than that of the engine itself. Figure 5.3 shows a typical small vessel engine compartment.

It should be noted that the vessels of interest are generally not required by regulation to have a fixed fire extinguishing system installed. However, many owners do install such systems due to general concern over vessel safety and insurance premium concerns.

Figure 5.3
Typical Small Vessel Engine Compartment



As identified by survey work completed during this project and discussed earlier, many of the systems that have been installed are homemade systems based on off-the-shelf portable extinguishers.

The NFPA-12 regulation indicates flooding factors of 0.072 and 0.067 for protection of spaces up to 140 cu. ft. (4.96 m^3) and between 141 and 500 cu. ft. (4.99 and 14.2 m^3) respectively. Thus, a 5 lb. cylinder can protect a space up to 69.44 cu. ft. (5/0.072=69.44) or 1.97 m^3 and two 5 lb cylinders or a single 10 lb. cylinder can protect a space up to 149.25 cu. ft. (4.23 m^3). These volumes correspond to the types of engine compartments mentioned above.

ULC approved fixed systems are available in 10 lb. cylinder size but were not available in the 5 lb. cylinder size. In order to provide 5 lb. ULC approved protection it was necessary to either enlist a manufacturers assistance in developing a ULC approved 5 lb. system or use an existing 10 lb. system and design for protection against over-pressurization.

6. MARKET RESEARCH

In Canada, numerous distributors provide CO_2 fire extinguishing equipment. However, the number of companies that actually manufacturer the equipment distributed by these companies is limited.

Until recently, complete small volume, fixed CO_2 firefighting systems were not readily available due to difficulty in obtaining small volume CO_2 cylinders. Currently, small fixed CO_2 cylinders specifically for fixed firefighting systems are readily available and complete small volume fixed CO_2 firefighting systems are available. The primary suppliers of this equipment are:

- Kidde,
- Pyrene,
- SES-Cease Fire,
- Kinge-Kerr, and
- Flame Tamer.

For fixed CO_2 firefighting systems, Kidde is estimated to have over 60% of the Canadian market and Pyrene about 20% of the market. SES-Cease Fire and Flame Tamer are relatively new manufacturers. Current price quotes for small fixed CO_2 firefighting systems from Kidde, Pyrene and SES-Cease Fire are presented in Table 6.1 (a), (b) and (c).

SES-Cease Fire and Kidde show similar pricing with a 35 lb. base system costing on the order $2,100. SES-Cease Fire and Pyrene both offer smaller systems (10, 15 and 20 lb.). For these smaller systems, base system prices are approximately $2,500, $2,600 and $2,700 respectively from Pyrene and $1,500, $1,600, and $1,700 from SES-Cease Fire.

From the survey work described in Section 4, the cost for systems including two 20-25 lb. cylinders was approximated on the order of $600-$650. The price of proper fixed CO_2 firefighting systems is undoubtedly the major factor leading to small vessel owners creating their own systems based on portable CO_2 fire extinguishers.

There are a large number of sources for CO_2 portable extinguishers throughout Canada including specialized marine fire-protection equipment distributors, marine chandlery and general fire and safety suppliers. However, as with fixed systems, the number of actual manufacturers is limited. The major manufacturers are:

- Amerex
- Chemetron
- Chubb
- Flag
- General
- Kinge-Kerr
- Pyrene
- Williams

Table 6.1
Fixed CO2 Extinguishing System Costs

Fixed CO2 Extinguishing Systems								
Cylinder Size [lb.]	10	15	20	25	35	50	75	100
ANSUL								
Volume Protected (NFPA-12) [cu. ft.]	150	225	300	-	500	800	1200	1600
Volume Protected (CSI) [cu. ft.]	200	275	500	-	900	1200	1500	2250
Price [$ Cdn.]	1250	1350	1550	-	1650	1900	2000	2150
KIDDE								
Volume Protected [cu. ft.]	-	-	320	400	560	800	1200	1600
Price [$ Cdn.]	-	-	1067	1067	2087	2133	2239	2782
PYRO-CHEM								
Volume Protected [cu. ft.]	160	240	320	-	-	800	1240	1600
Price [$ Cdn.]	2475	2975	3725	-	-	3665	3700	3859
SEA-CURE (ADE FIRE)								
Volume Protected [cu. ft.]	160	240	320	-	560	800	1200	1600
Price [$ Cdn.]	1600	1774	1650	-	2150	2200	2362	2950

Notes

[1] Ansul pricing provided by DBC Marine.
- Price includes charged cylinder, bracket, manual actuator, flexible discharge hose, discharge nozzle(s), operation signs, installation maintenance manual and engineering costs.
- Price does not include installation, installation materials, pressure switches/relays for ventilation control, alarm devices, time delay or verification of equipment on completion of installation.
- Taxes extra, FOB warehouse.

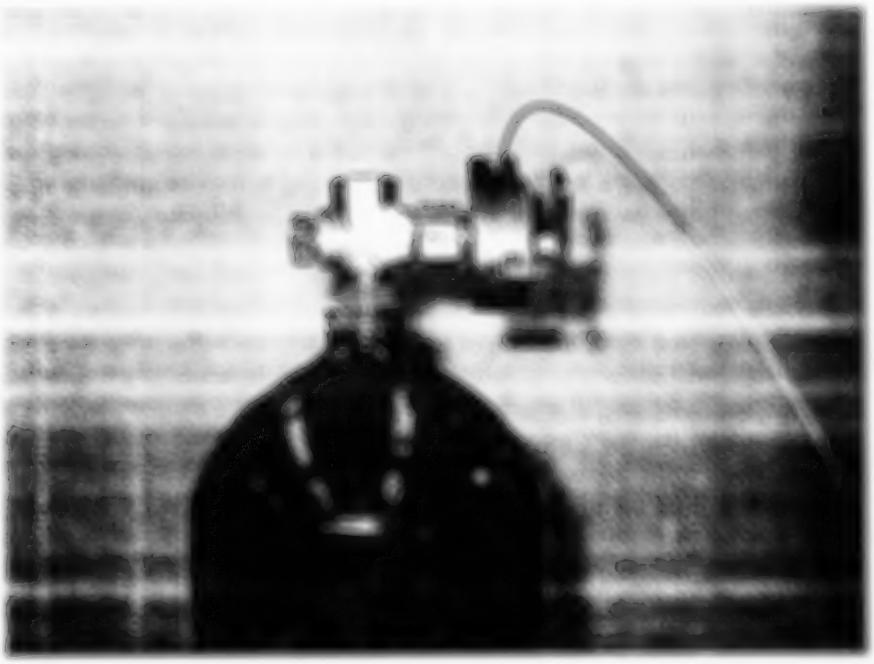
[2] Kidde pricing provided by MEPI
- Price includes cylinder, discharge head, 3/4 in. flexible hose, 2 cylinder straps, lever operated control head, 2 x 1/2 in. nozzles and engineering costs.
- Price does not include pressure switches for shutdown of fans or engine room dampers, 30 second time delay, siren for evacuation, instant release of gas to protected space, piping or installation materials, discharge testing.

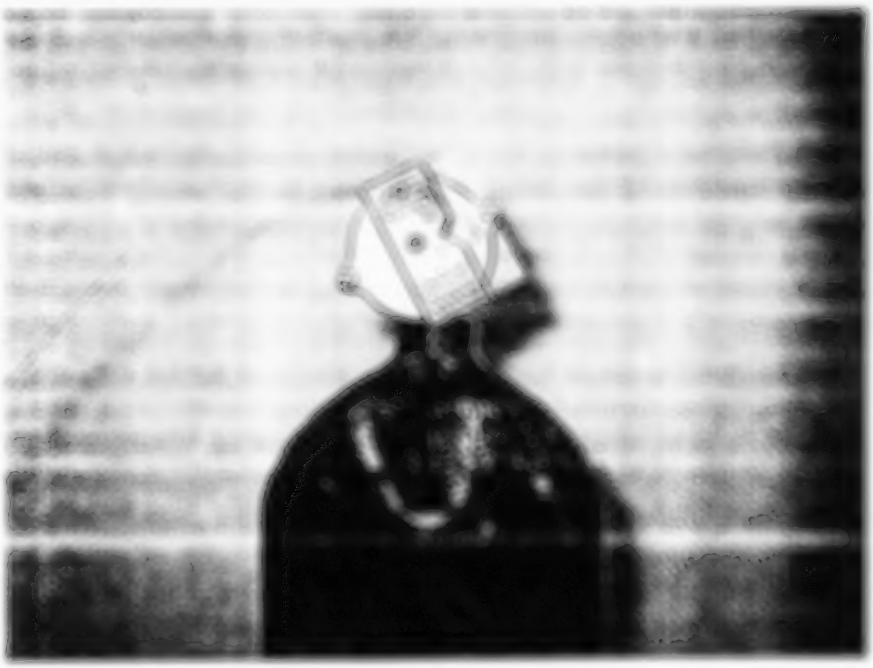
[3] Pyrene pricing provided by MEPI
- Price includes cylinder, 1/2 in. flexible discharge hose, 2 cylinder straps, manual actuator assembly, 2 x 1/2 in. nozzles and engineering costs.
- Price does not include pressure switches for shutdown of fans or engine room dampers, 30 second time delay, siren for evacuation, instant release of gas to protected space, piping or installation materials, discharge testing.

[4] SEA-Cure Fire pricing provided by MEPI
- Price includes cylinder, manual actuator, cylinder strap, 1/2 in. flexible discharge hose w/ check valve, 1/2 in. discharge nozzle, 3/4 in. straight thread to 1 in. NPT adapter and engineering costs.
- Price does not include pressure switches for shutdown of fans or engine room dampers, 30 second time delay, siren for evacuation, instant release of gas to protected space, piping or installation materials, discharge testing.

Recently, ANSUL has obtained ULC approval for a 5 lb. fixed system that was developed for a military application as shown in Figure 6.1 [7]. Preliminary pricing for this system has been stated as approximately $500 U.S. (~ $750 Cdn.). This price is very competitive against existing larger volume fixed systems (~$2,000 Cdn.) and is inexpensive enough to offer a financially realistic alternative to portable extinguishers.

Figure 6-1
[illegible] Blood System





5. [illegible]

Guidelines developed for surveyors inspecting homemade fire extinguishing systems are presented in each sub-section following a listing of relevant pre-existing regulations.

Review of relevant literature provides a base understanding of how different authorities have dealt with the various areas of concern. The guidelines presented in this section are derived directly from existing literature given the consideration to small vessels operations.

Development of these guidelines was undertaken with five primary goals in mind as outlined below.

1) Safety – The guidelines must promote safe system design. That is, components must be able to safely handle system pressure (i.e. no leakage at connections at expense of piping) and the risk of accidental exposure of personnel to carbon dioxide gas must be minimized.

2) Effectiveness – The guidelines must ensure that the system will be effective in extinguishing fires in the space being protected. That is, the quantity of gas and distribution of gas must be suitable for the purpose intended.

3) Reliability – The guidelines must ensure that the system operates reliably. That is, system design must be such that the risk of failure to operate is minimized (i.e. cylinder bank protected from corrosion and piping system protected from fire damage).

4) Comprehensive – The guidelines must cover all system design elements critical to system safety, effectiveness and reliability as noted above.

5) Usable – The guidelines must be written in a simple, clear manner that reflects the practicality of small vessel operations.

Appendix A to this report presents design and installation guidelines developed by ANSUL for small fixed CO2 fire extinguishing systems. ANSUL's guidelines directly reflect the work carried out in this study and the guidelines for surveyors in this submission.

5 (1) [redacted]

This section provides background information and discussion regarding the type and size of vessel to which the standards will apply.

[redacted]

[redacted] [redacted]

(1) These [redacted] to new fishing vessels over 24 m in length as [redacted] that are not acting ships.

(2) Every vessel, the construction of which is commenced after May 15, 1978 and to which a carbon dioxide smothering system has [redacted] must be maintained and [redacted] with the requirements of section 7 of Schedule III of the Fire Detection and Extinguishing Equipment Regulations (C.R.C., c. 1009).

[redacted] [redacted]

(1) These [redacted] to fishing vessels that [redacted] 24 but not [redacted] 45 [redacted] 24 m in length and [redacted] to [redacted] acting ships.

(2) There is no [redacted] of fixed fire extinguishing systems, only a requirement for portable extinguishers.

(3) Every fire extinguisher required by these Regulations shall be of a type approved by

(a) the Underwriters' Laboratories of Canada;
(b) the Department of Trade and Industry of Great Britain;
(c) the United States Coast Guard; or
(d) the Board.

[redacted] [redacted]

(1) [redacted] These standards [redacted]

(a) new ships; and
(b) existing ships which are modified to such an extent that the Board deems it reasonable and practicable to apply any part of these standards to any previous vessel.

(2) [redacted]
Parts I and II apply to fishing vessels ships, [redacted] to [redacted], Parts III through VII apply to various other passenger ships, [redacted] to number of passengers, [redacted] passengers, and voyage [redacted].

[redacted] [redacted]

(1) These Regulations apply to

(a) ships [redacted] 15 GRT that carry more than 12 passengers;
(b) passenger ships over 15 GRT; and
(c) non-passenger ships over 15 GRT with crew

[3] [3] These Regulations do not apply to fishing vessels (CSA-31 and CSA-75), drilling units, air cushion vehicles of hydrofoil craft, nuclear powered ships, ships operated by the Canadian Armed Forces and pleasure yachts.

TP 11737: Standards for the Construction and Inspection of Small Passenger Ships

[2.1] These standards do not apply to ferry vessels or dynamically supported craft.

[2.2] These standards apply to new small passenger vessels that are used in the transport of one or more passengers, are restricted to voyages not more exposed than home-trade Class III or inland waters Class II, and are no more than 24.0 m in length that;

(a) exceed 15 but are not more than 150 GRT, and carry not more than 100 unberthed passengers or 25 berthed passengers, or
(b) do not exceed 15 GRT and carry more than 12 passengers but not more than 100 unberthed or 25 berthed passengers.

[20.5] The propulsion machinery space shall be protected by a fixed gas fire extinguishing system complying with the Fire Detection and Extinguishing Equipment Regulations (CSA-20).

Nordic Boat Standard

[4.1] Boats with a length overall greater than 8 m shall have a fixed fire extinguishing system in the engine room.

Lloyd's Register of Shipping - Part 6, Chapter 4, Section 4 (Jan. 1998)

[1.1.1] Cargo ships of less than 500 GRT, fishing vessels of 12 m length and over but less than 45 m and ships not fitted with propelling machinery.

Conclusions

This project was initiated with small fishing vessels and small passenger vessels (i.e. tour boats carrying not more than 12 passengers) as the target vessels of interest, many of the tour boats in operation are converted fishing vessels. These are the vessel types which regulatory surveyors identified as being equipped with portable CO_2 extinguisher based fixed fire extinguishing systems. Survey work conducted during this project confirms that, although not exclusively so, these types of vessels are those most commonly found fitted with portable extinguisher based fixed fire extinguishing systems.

An essential requirement of any new standards is that there be no ambiguity regarding what the vessel types to which these new standards apply. Under the Canadian regulatory regime, CSA-31 and CSA-75 govern large and small fishing vessels respectively. The cut-off distinguishing large from small fishing vessels is: 24.4 m length and 150 GRT. Small passenger ships carrying not more than 12 passengers and less than 15 GRT are essentially un-regulated. Passenger ships less than 15 GRT carrying more than 12 passengers and ships over 15 GRT but less than 150 GRT

carrying less than 100 unberthed (or 25 berthed) passengers are subject to TP-11717. This ship safety publications coverage of fixed CO_2 systems is limited to referencing CSA-20. CSA-20 is the Canada Shipping Act Fire Detection and Extinguishing Equipment Regulations, which reflect Canada's adoption of SOLAS.

To avoid overlap with existing regulations and giving due regard to the vessel types of particular interest (small commercial fishing vessels and tour boats) it is proposed that the standards developed be applicable to all vessels less than 24.4 m in length and not exceeding 150 GRT carrying not more than 12 passengers.

Definition of the scope of applicability typically depends on assigning a length or tonnage cut-off point. Assigning such a point is somewhat arbitrary as it is the protected space volume and the quantity of smothering gas required that drives system design requirements. A more meaningful application cut-off point would be defined by bottle weight. It is suggested that the standards be applicable only to systems with a total bottle weight of approximately 100 lb. of carbon dioxide. This figure is also somewhat arbitrary, however, systems larger than this are deemed sufficiently complex to demand professional installation by certified manufacturers representatives.

7.2 Plans and Data

This section provides background information and discussion regarding the plans and system data required for a fixed fire extinguishing system.

TP-4813: Schedule IV

[1. (1)] General schematic and description of the space being protected including indication of the location of doors, vents, hazardous items, dimensions of space. For the space being protected, an electrical schematic and wiring deck plan are requested.

[1. (2)] Piping and fittings schedule identifying size and equivalent lengths of pipes, fittings and hose.

[1. (3)] Drawings for;
- gas storage containers (cylinders) and rating,
- discharge heads,
- release mechanism,
- fire detection system,
- alarm,
- valving, and
- any other pertinent details such as ventilation shut down etc.

[1. (4)] Calculations verifying gas concentration and discharge time.

[1. (5)] System manual containing operating and maintenance instructions.

NFPA-12 (1993): Chapter 1 - General

[1-6.2/6.2.1] Plans and calculations submitted for approval before installation of system begins. Plans to be prepared by a person fully qualified in the design of carbon dioxide fire extinguishing systems. Plans to be drawn to an indicated scale or suitably dimensioned. Plans to be such that they can be easily reproduced.

[1-6.2.2] Plans to be in sufficient detail to enable evaluation of hazards and system effectiveness; should include materials involved in the protected hazard, location of hazards, enclosure limits and isolation of hazards and the area surrounding that might affect protected hazards.

[1-6.2.3] Plan details should include information and calculations on:
- the amount of CO_2,
- location and flow rate of each nozzle including orifice area,
- location and size of piping, hose and fittings,
- location and size of CO_2 storage facility,

[1-6.2.4/6.2.5] When field conditions necessitate substantial change from the approved plans, the change must be submitted to the authority having jurisdiction; submitted as "as-installed" plans.

[1-6.2.6] Instruction and maintenance manual including sequence of operation and system plans to be maintained in protective enclosure.

Lloyd's Register of Shipping - Part 6, Chapter 4, Section 4 (Jan. 1998)

[1.2.3] For fire extinguishing, the following plans are to be submitted:
(a) A general arrangement plan showing the disposition of all firefighting equipment including the fire main, the fixed fire-extinguishing systems in the main machinery spaces; the disposition of the portable and non-portable extinguishers and the types used; and the position and details of the firemen's outfits.
(b) A plan showing the layout and construction of the fire main, including the main and emergency fire pumps, isolating valves, pipe sizes and materials and the cross connections to any other system.
(c) A plan showing the details of each fixed firefighting system, including calculations for the quantities of the media used and proposed rates of application.

Guidelines

The submission of plans to a regulatory authority is not intended to be a technical or financial burden. However, a fixed firefighting system is an important item of safety equipment. Furthermore, the extinguishing medium (CO_2) is hazardous to personnel. Therefore, there must be high confidence that the system meets the intended purpose and will operate effectively when required. Submission of basic system design parameters to a technical/regulatory authority for expert review provides an increased level of confidence that this will be the case.

An important issue to be considered here is the availability of regulatory resources for reviewing of plans submitted. In addition, those responsible for plan approval must have a basic knowledge of systems design, problems that can occur and an understanding of what is acceptable and what is not. The resources (time) and expertise (technical knowledge regarding CO_2 firefighting system design) required for plan approval may be minimized by giving careful consideration to the information that is required to be included in plans being submitted for approval. Plans submitted for approval should:

- Include adequate detail regarding all critical design information (i.e. volume of space being protected, quantity of gas, length of pipe runs etc.),
- Clearly define the information required in a manners such that there is no ambiguity or question regarding what is being asked,
- Be such that confirmation of the information reported can be readily verified during surveying.

Clear definition in the Standard of system design calculations, measurements to be taken and materials and/or equipment items to be used will allow the regulatory authorities to quickly assess a system. Calculations may be readily verified and arrangements checked against accepted norms.

7.3 Carbon Dioxide Quantity

This section provides background and discussion regarding the quantity of carbon dioxide required for a fixed fire extinguishing system. That is, the weight of the portable extinguishers to be used.

USCG NVC 6-72: II Carbon Dioxide

[A.3] Reduction of oxygen content to 15% is sufficient to extinguish most fires. Developing a CO_2 concentration of 28.5% will reduce oxygen content to 15%.

[A.3] Volume of CO_2 required to develop a giver concentration, assuming free efflux, is given by the following formula (references NFPA):

$VC = \log_{10}[100 / (100 - \%CO_2)] / 0.434$
where, VC = volume of CO_2 added per volume of space,

[A.3] Assume 1 lb. (0.45 kg) of carbon dioxide expands to 9 cu. ft. (0.95 m^3) when released at 86°F (30°C).

[A.4] As the volume of a space increases the proportional amount of CO_2 required to protect that space decreases. The smaller the volume of a space, the greater the ratio of surface area to volume and consequently, the greater the ratio of access openings to volume. Therefore, for smaller spaces there is a relatively greater chance of CO_2 leakage from the space. An additional factor is that of ventilation. While mechanical ventilation systems are required to be shut down and ventilators closed upon actuation of a system, the presence of a ventilation system allows loss of some extinguishing gas.

46 CFR, Subchapter T

[181.20-10] (a) The number of pounds of carbon dioxide required for each space protected shall be determined as follows:
(1) For cargo spaces, the number of pounds required shall be equal to the gross volume of the space in cubic feet divided by a factor of 30.
(2) For machinery and fuel tank spaces, paint lockers, oil rooms and similar hazardous spaces, the number of pounds required for each space shall equal to the gross volume of the space divided by the appropriate factor noted in Table 181.20-10(a)(2).

Table 181.20-10(a)(2)

Gross volume of compartment [cu. ft.]		Factor
Over -	Not Over -	
-	500	15
500	1600	16
1600	4500	18
4500	-	20

(b) A separate supply of carbon dioxide need not be provided for each space protected. The total supply shall be at least sufficient for the space requiring the greatest amount.

NFPA-12 (1993): Chapter 2 - Total Flooding Systems

[2-2.2] Since the efficiency of carbon dioxide systems depends on the maintenance of an extinguishing concentration of carbon dioxide, leakage of gas from the space shall be kept to a minimum and compensated by applying extra gas.

Where possible, openings such as doorways, windows, etc. shall be arranged to close automatically before or simultaneously with discharge. Where forced air systems are involved, they shall be shut down or closed, or both, before discharge.

[2-3.2] Regarding CO_2 concentration ... in no case shall a concentration less than 34% be used. Table 2-3.2.1 identifies a theoretical concentration of 28 and minimum design concentration of 34 for gasoline.

[Appendix A-2-1] Theoretical formula presented above. CO_2 expansion noted here as 9 cu. ft./lb. (0.56 m^3/kg).

[2-3.3] Volume requirements are simplified, given due consideration to protected space volume and "free efflux", into "Volume Factors". The volume of space to be protected [cu. ft.] is divided by an appropriate volume factor [lb. of CO_2 / cu. ft.] to arrive at the weight of CO_2 required. Volume factors given in Table 2-3.3 as noted below:

Table 2-3.3: Flooding Factors (34%)

Space Volume [cu. ft.]	Volume Factor [cu. ft./lb. CO_2]	Calculated Quantity Not Less Than [lb. CO_2]
up to 140	14	-
141 – 500	15	10
501 - 1,600	16	35
1,601 - 4,500	18	100
4,501 - 50,000	20	250
over 50,000	22	2,500

[2-3.3.2] The Volume Factors given in the table above are used to determine the basic quantity of carbon dioxide to protect an enclosure containing a material requiring a design concentration of 34%. The graded Volume Factors account for the fact that a smaller space has proportionately more boundary area per enclosed volume than a larger space; greater proportionate leakages are anticipated. Example: 350 cu. ft. (9.9 m^3)engine room space to be protected. From the table above the Volume Factor = 15. Thus, the CO_2 cylinder for this system should be 300/15 = 23.33 lb. (10.6 kg). The nearest standard cylinder size meeting this minimum requirement is 25 lb.

[2-3.3.1] In calculating the volume of a protected space, due allowance may be made for permanent non-removable impermeable structures materially reducing the volume.

[2-3.4] For materials requiring a design concentration over 34%, the base quantity of CO_2 required is modified by applying a conversion factor. Additional quantities of CO_2 shall be provided to compensate for any special condition that may adversely affect extinguishing efficiency.

[2-3.5.1] Any openings that cannot be closed at the time of extinguishment shall be compensated for by the addition of a quantity of CO_2 equal to the anticipated loss at the design concentration during a 1-minute period. Extra amount discharged through the regular distribution system.

[2-3.5.2] For ventilating systems that cannot be shut down, additional CO_2 shall be added to the space through the regular distribution system. Additional amount computed by dividing the volume moved by the Volume Factor. Extra multiplied by the Conversion Factor when the design concentration is over 34%.

[2-3.5.3/3.5.4] For applications where the normal temperature of the protected space is above 200°F (93°C), a 1% increase shall be added to the calculated CO_2 required for each additional 5°F (-15°C)above 200°F (93°C). For applications where the normal temperature of the protected space is below 0°F (-18°C), a 1% increase shall be applied for each degree Fahrenheit below 0°F (-18°C).

A flooding factor of 8 cu. ft./lb. (0.23 m^3)shall be used in ducts and covered trenches.

TP-11717: Standards for the Construction and Inspection of Small Passenger Ships

[20.6] Where the vessel is constructed of wood, fibre-reinforced plastic or aluminum, the system shall be provided with two complete and independent charges of gas.

TP-4813: Schedule IV

[5. (1)] Where the volume of free air contained in air receivers in any such space is such that if released in such space in the event of fire, such release of air within that space would seriously affect the efficiency of the fixed fire-extinguishing system, additional fire-extinguishing capacity shall be provided to compensate for the free air equivalent of the pressurized air.
[5. (2)] Where the quantity of extinguishing medium is required to protect more than one space; (a) the quantity of medium available need not be more than the largest quantity required for any one space so protected; and (b) the arrangements for its storage and release shall be such that compliance with 11(1) {cargo space concentration}, 11(2) {machinery space concentration}, 11(3) {hazardous storerooms concentration}, 16(2) {halon} and 16(3) {halon}.

[5. (3)] Where two or more protected spaces are not entirely separate they shall be considered as forming one space.

[11. (1)] For cargo spaces, the quantity of medium available shall unless otherwise prescribed be sufficient to give minimum volume of free gas equal to 30% of the gross volume of the largest cargo space so protected in the ship; special requirements if fuelled motor vehicle on board.

[11. (2)] For machinery spaces, the quantity of medium available shall be sufficient to give a minimum volume of free gas equal to the larger of the following volumes, either
(a) 40% of the gross volume of the largest machinery space protected, the volume to exclude that part of the casing above the level at which the horizontal area of the casing is 40% or less of the horizontal area of the space concerned taken midway between tank top and the lowest part of the casing; or
(b) 35% of the gross volume of the largest machinery space so protected, including the casing, provided that the above mentioned percentages may be reduced to 35% and 30% respectively for Group II ships of less than 2,000 GRT.

[11. (3)] The quantity of medium carried for hazardous storerooms, such as oil and paint lockers shall be sufficient to give a minimum volume of free gas equal to 40% of the gross volume of the protected space.

[11. (4)] For the purpose of this section the volume of free carbon dioxide shall be calculated at 0.56 m^3/kg.

[11. (5)] For machinery spaces, the fixed piping system shall be such that 85% of the gas can be discharged into the space within 2 minutes.

[11. (6)] For machinery spaces, the distribution arrangements shall be such that approximately 15% of the required quantity of carbon dioxide is led to the bilge areas; distribution to other high-risk areas such as boiler flats shall be specially considered.

Lloyd's Register of Shipping - Part 6, Chapter 4, Section 4 (Jan. 1998)

[4.1.7] Where the volume of free air contained in air receivers in any space such that, if released in such a space in the event of fire, such release of air within that space would seriously affect the efficiency of the fixed fire-extinguishing system, an additional quantity of fire-extinguishing medium is to be provided.

[4.1.13] Where the quantity of extinguishing medium is required to protect more than one space, the quantity of medium available need not be more than the largest quantity required for any one space so protected.

[4.2.1] For machinery spaces the quantity of carbon dioxide is to be sufficient to give a minimum volume of free gas equal to the larger of the following volumes, either;
(a) 35% of the gross volume of the largest machinery space so protected, the volume to exclude that part of the casing above the level at which the horizontal area of the casing is 35% or less of the horizontal area of the space concerned taken midway between tank top and the lowest part of the casing; or
(b) 30% of the gross volume of the largest machinery space protected, including the casing.

[4.2.2] For the purpose of this paragraph, the volume of free carbon dioxide is to be calculated at 0.56 m^3/kg.

[4.2.3] For machinery spaces, the fixed piping system is to be such that 85% of the gas can be discharged into the space within two minutes.

[4.2.4] For machinery spaces, the distribution arrangements are to be such that approximately 15% of the required quantity of carbon dioxide is led to the bilge areas.

SOLAS - Chapter II-2, Regulation 5

[2.1] For cargo spaces the quantity of carbon dioxide available shall, unless otherwise provided, be sufficient to give a minimum volume of free gas equal to 30% of the gross volume of the largest cargo space so protected in the ship.

[2.2] For machinery spaces, the quantity of carbon dioxide carried shall be sufficient to give a minimum volume of free gas equal to the larger of the following volumes, either:
(.1) 40% of the gross volume of the largest machinery space so protected, the volume to exclude that part of the casing above the level at which the horizontal area of the casing is 40% or less of the horizontal area of the space concerned taken midway between the tank top and the lowest part of the casing; or
(.2) 35% of the gross volume of the largest machinery space protected, including the casing; provided that the above-mentioned percentages may be reduced to 35% and 30% respectively for cargo ships of less than 2,000 tons gross tonnage; provided also that if two or more machinery spaces are not entirely separate they shall be considered as forming one space.

[2.3] For the purpose of this paragraph, the volume of free carbon dioxide shall be calculated at 0.56 m^3/kg.

[2.4] For machinery spaces, the fixed piping system shall be such that 85% of the gas can be discharged into the space within 2 min.

Nordic Boat Standard

[4.6] The amount of carbon dioxide shall be 1.5 kg/m^3 (0.0936 lb./cu. ft.) of the gross volume of the engine room. At least half the filling ratio shall be achieved in not more than 10 seconds.

Guidelines

A fundamental principle of fixed fire extinguishing system design is that there is enough smothering gas to extinguish a fire in the protected space. In the case of small vessels, our primary concern is an engine room fire. The primary hazard in this space is a diesel, oil or gasoline fire. The theoretically minimum gas concentration required for extinguishment is 28%; this concentration is a volume (as opposed to weight) percentage. In considering the concentration required for design purposes, there are a number of problems to consider:

- We can assume free efflux, however as carbon dioxide is injected into the space it will mix with the air within the space, air that is displaced will include some carbon dioxide.
- The space itself may not be completely gas-tight. As the heavier carbon dioxide (air density ~1.21 kg/m^3, carbon dioxide ~ 1.98 kg/m^3) gas enters the space and sinks it may leak out of the space.

Designers recognize these problems. For flammable materials, NFPA recommends that the theoretical concentration be increased (20%) to 34% for design purposes. Existing literature on marine installations suggests 30% concentration for cargo spaces and between 30 and 40% concentration for machinery spaces; it is noted that marine literature has additional factors of safety built in through via the volume factor.

Carbon dioxide is stored in pressurized containers. Portable extinguishers are considered 'high-pressure' containers and store gas at about 750 psi or 5.2 MPa (actual pressure varies with temperature). A portable extinguisher is referred to by the weight of gas it stores (i.e. a 20 lb. bottle). The accepted expansion rate for CO_2 is 9 cu. ft./lb. (0.56 m^3/kg). When specifying the quantity of carbon dioxide gas required to protect a space, it is common to define a flooding factor or volume factor. The weight of gas required to protect a space is determined by dividing the volume of the space by the correct flooding factor.

For example, consider a 501 cu. ft. (14 m^3) space, referring to NFPA Table 2-3.3 we identify a flooding factor of 16. Thus a 501/16 = 31.31 lb. bottle is indicated, however, this table also identifies a minimum size of 35 lb.. It is noted by calculating 34% of 501 cu. ft. (14 m^3) is 170.34 cu. ft. (4.8 m^3), and then dividing by the expansion rate of 9 cu. ft./lb. (0.56 m^3/kg) to arrive at an 18.93 lb. bottle requirement (an implied flooding factor of 501/18.93 = 26.47). Thus, it can be seen that the flooding factor incorporates a factor of safety. By performing the same calculations for the volumes noted in the NFPA Table the following safety factors are determined (higher volumes omitted, as they will not be relevant to small vessels):

Flooding Factors – Implied Safety Factor

Space Volume [cu. ft.]	Flood Factor [cu. ft./lb. CO_2]	Required Bottle Weight	Calculated Bottle Weight	Implied Safety Factor
140	14	10	5.29	1.89
500	15	33.33	18.89	1.76
1,600	16	100	60.44	1.65
4,500	18	250	170.00	1.47

This safety of factor reduces as volume of the space increases; it is assumed that a small space has a greater surface area (leakage possibility) to volume ratio than a larger volume.

In defining the quantity of gas required in a Standard, two approaches can be taken:

[1] Perform a detailed analysis of the volume and venting of the space to be serviced and then calculate the gas quantity required based on the volume calculated giving due

consideration to space permeability, leakage, free efflux and air circulation using an accepted value for gas concentration, expansion and flow rate.

[2] Give consideration to relevant vessel types and engine room arrangements and build an inherent safety factor into the standards and simply present a required bottle size for a given engine room volume. By incorporating a sufficient "factor of safety", engine room volume could be based on a simple approximation based on a simple empirical formula such as a constant (safety of factor) x vessel beam x vessel depth x engine room length.

Option [2] above is deemed the most appropriate approach for the small vessels, this is also the approach adopted by the literature reviewed. The small vessels of interest to this study will have relatively small volume engine rooms that can be serviced by small bottles (i.e. a single 20 or 25 lb. bottle as opposed to banks of 100 lb. bottles). For the small gas volume needed for such vessels, an increase in the amount of gas required will not have a large cost implication. For example, a 25% increase in gas quantity requirement for a 20 lb. bottle means changing from a 20 lb. to a 25 lb. bottle.

A conservative starting point for portable extinguishers based systems would be to adopt the 40% gross volume requirement and a simple calculation methodology as follows:

L_{ER} = Maximum distance between engine room bulkheads [ft.]
H_{ER} = Maximum height from keel to deck above the engine room [ft.]
B = Vessel beam [ft.]
V_{ER} = Estimated engine room volume = L_{ER} x H_{ER} x B [cu. ft.]

Using V_{ER}, reference the table below to select the nearest standard bottle size.

V_{ER} versus minimum bottle size

V_{ER} [cu. ft.]	Minimum Bottle Size [lb. CO_2]
Up to 119	10
120 – 181	15
182 – 255	20
256 – 319	25
320 – 382	30
383 – 446	35
447 – 509	40
510 – 680	50

The table presented above gives the smallest standard bottle size for the estimated engine room volume calculated. This table is based on a 40% volume gas concentration requirement and alh_2 = the safety factors applied by NFPA Table 2-3.3.

With respect to the calculation and table noted above, the following notes are made regarding the Standard:

- Reasonable gas tight integrity of bulkheads and penetrations is presumed. Bulkheads need not be gas-tight in formal sense of the word, however, excessive leakage is unacceptable. For example, engine room with open hatch extending the length of the vessel will allow excessive escape of gas.
- Venting: Excessive venting of the machinery space will diminish concentration realized; vents should closed where possible.
- Vessels operation: Operation of small vessels with engine room hatches open for venting is not uncommon, this should be avoided.
- Methodology: The calculation is sufficiently conservative to allow ignoring of the casing volume.

[illegible]

This section provides background and discussion regarding venting of the protected space.

[illegible]

[illegible] For very tight enclosures, the area necessary for free venting may be calculated from the following formula (assuming expansion to [illegible] at [illegible]):

$$A = [illegible] / ([illegible])$$

where: A = free venting area [sq. in.]
[illegible] = rate of expansion [lb. mixture / sq. in.] at orifice area (see 1000)
[illegible] = allowable or rapid of enclosure [lb./sq. ft.] (see 5) if not known)
A = total orifice area [sq. in.]

[illegible]

[illegible] Density and leakage path or at doors, windows, and dampers, though not easily apparent or easily calculated, have been found to provide sufficient relief for normal rubber sheeted flooding systems without the need for additional venting. Note: This comment based on buildings not marine structures.

[illegible] Equation shown in above [illegible] presented [illegible] is the source.

[illegible]

[illegible] Ventilation openings and their closing devices shall be so arranged that a damaging overpressure will not arise a release of the extinguishing system.

[illegible]

[illegible] Subject to subsection (2) means shall be provided for automatically stopping all ventilation fans serving the protected space so that at least the minimum necessary concentration of the extinguishing medium being released shall be created in the protected space, since the continuing operation of any other machinery or equipment associated with a hazard being protected could contribute to increasing the fire in the hazard or create any other unsafe conditions, the source of power so fed shall be automatically shut off.

[illegible] In ventilated enclosures, it is not necessary to shutdown closed loop ventilation systems in which exhaust air is returned to the protected space.

[illegible] Means shall be provided to close all openings, which may admit air or allow gas to escape from a protected space. Such means shall be automatic where gas release is imminent.

[redacted] Regulation 4 Shipping - Part 15 Chapter 5: Section 15 Reg. 1995

[redacted] means an in the provided a close of openings, which may other or a other gas is escape from a protected space

[redacted] Ventilation fans are to be capable of being stopped and main inlets and outlets of ventilation systems should from outside the space being served

[redacted] Chapter II-2 Regulation 9

[redacted] Means shall be provided a close of openings, which may other or a other gas is escape from a protected space

[redacted]

Operations of gas free tug is running a possible. However, such a situation is deemed overly complex for the small vessel of interest. The primary concern is simple: that the concentration of gas exposed into the protected space is not diminished to an ineffective level due to mechanical venting and/or leakage from the space.

The only cause of concern with small spaces is the ingression of gas vapor or mixture is present within the engine room but is presumably damaging. Small vessel engine rooms are not typically constructed as close gas tight compartments. Leakage under pressure will occur. Furthermore, no main was assumes a fire / explosion pressure will be seen within the engine room. As pressure should not have an impact on a structure designed to withstand the forces of a mishap.

The candidate must provide comments regarding the effect of venting and the pressure in close vents and leaves and also associated venting given in shortage. The following is suggested:

- Means shall be provided for the closure of all openings (doorways, vents, hatches, doorways), which allow air into or would allow the escape of gas from the engine room.
- Means shall be provided for the shutdown of ventilation fans.

Subtitle

This section provides background and discussion regarding the fixed gas pressure containers.

TP 4913: Subsection IV

[7.(1)] *Every fixed pressurized container that is a shipping container shall be constructed, tested and marked in accordance with the requirements of the Canadian Transport Commission.*

[7.(2)] *Every fixed pressurized container except where covered as a fire extinguisher and which is not a shipping container shall be constructed, tested and marked in accordance with the requirements of (a) the American Society of Mechanical Engineers (ASME), Unfired Pressure Vessel Code (Section VIII), (b) an approved classification society, or (c)* the British Standards Institute.

[7.(3)] *Every pressurized gas container shall be permanently marked to specify the agent, tare and gross weight.*

[7.(4)] *Except for automatic systems, where containers are located within the protected space (below), every fixed pressurized gas container shall be fitted with an automatic pressure relief device venting to a safe location, which may be the approved storage space.*

[7.(5)] *The discharge from carbon dioxide or halon containers shall be maintained from the liquid contents of the containers by either: (a) fitting internal pipes, or (b) placing the discharge pipe at the lowest part of the container.*

[7.(6)] *means shall be provided to indicate if a container has been discharged.*

[7.(7)] *Means shall be provided as applicable for the crew to safely check the quantity and pressure of medium in the containers and also replace empty or defective containers.*

[9.(1)] *For total flooding systems and local application systems, storage temperatures shall be within a range from -18 to 54°C and 0 to 49°C, respectively, unless the system is designed for operation with storage temperatures outside these ranges, external heating or cooling may be used to keep the temperature within this range.*

[9.(5)] *High-pressure carbon dioxide supply shall be stored in containers to hold pressurized carbon dioxide in liquid form at atmospheric temperatures, corresponding to a nominal pressure of 5.86 MPa at 21°C.*

[9.(5)] *If not a shipping container, the design pressure shall be suitable for the maximum pressure developed at 54°C or at the maximum controlled temperature limit, but not less than a design pressure of 2.24 MPa.*

Lloyd's Register of Shipping - Part 6, Chapter 4, Section 4 (Jan. 1998)

[4.1.15] Means are to be provided for the crew to safely check the quantity of medium in the containers.

[4.1.16] Containers for the storage of fire-extinguishing media and associated pressure components are to be designed and tested to codes of practice recognized by LR having regard to their locations and the maximum ambient temperatures expected in service.

Guidelines

The excerpts above are concerned with bottle design. If the standards accept only approved portable extinguishers, then technical details may be dispensed with. However, the following points are of particular importance:

- Bottles are ULC, UL or equivalently approved and marked thus,
- Bottle markings including test dates etc. should be clearly visible.

7.6 Bottle Location

This section provides background and discussion regarding the location of gas bottles.

Nordic Boat Standard

[4.4] The bottles for extinguishing medium shall be positioned in a space where seawater splash, mechanical damage or temperatures above 50°C are not expected. Bottle must not be placed in the engine room.

TP-4813: Schedule IV

[6(1)] Except as otherwise allowed and applicable in Section 12 {automatic systems for infrequently occupied spaces}, 17, 18, 19 and 20 {halon}, pressure containers required for the storage of fire-extinguishing medium shall be located outside protected spaces in accordance with (2) {below}.

[6.(2)] Where the fire-extinguishing medium is stored outside a protected space it shall be in accordance with the requirements of the Hull Construction Regulations {CSA-28}.

[6.(3)] Containers and accessories shall be located and arranged that inspection, testing, recharging and other maintenance is facilitated and interruption to protection is held to a minimum.

[6.(4)] Containers shall be located as near as possible to the hazard or hazards they protect, but except as otherwise allowed and applicable in sections 12 {automatic systems for infrequently occupied spaces}, 17, 18, 19 and 20 {halon}, they shall not be located where they will be exposed to a fire or explosion in these hazards that is likely to impair system performance.

[6.(5)] Containers shall not be located so as to be subject to severe weather conditions or be subject to mechanical, chemical, or other damage; when excessive climatic or mechanical exposures are expected, suitable guards or enclosures shall be provided.

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[4.1.14] Pressure containers required for the storage of fire-extinguishing medium are to be located outside protected spaces in a room, which is situated in a safe and readily accessible position and effectively ventilated. Any entrance to such a storage room is to preferably be from the open deck and in any case be independent of the protected space. Access doors are to open outwards, and bulkheads and decks including doors and other means of closing any opening therein, which form boundaries between such rooms and adjoining enclosed spaces are to be gas-tight.

46 CFR, Subchapter T

[181.20-30] Cylinders

(a) Cylinders shall be securely fastened and supported, and where necessary protected against injury.
(b) Cylinders shall be mounted in an upright position or inclined not more than 30° from vertical. However, cylinders that are fitted with flexible or bent siphon tubes may be inclined not more than 80° from the vertical.
(c) All cylinders used for storing carbon dioxide must be fabricated, tested, and marked in accordance with the requirements of 147.60 and 147.65 of this chapter.
(d) Cylinders shall be so mounted as to be readily accessible and capable of easy removal for recharging and inspection, including weighing.
(e) Where subject to moisture, cylinders shall be so installed as to provide a space of at least 2 in. between the flooring and the bottom of the cylinders.

Guidelines

Although the excerpts above may seem obvious to those familiar with carbon dioxide system design, they may not be so obvious to vessel operators. The comments that should be reiterated in the standards are as follows:

- Bottles shall be stored in the upright position.
- Bottles shall be securely fastened and supported, such mounting should allow for easy removal of bottles for recharging, inspection and weighing.
- Bottles shall be positioned so that the bottle markings may be easily read and the discharge head easily accessed for inspection.
- Bottles shall not be stored in accommodation spaces or other space frequented by personnel.
- Bottles shall not be located within the engine room.
- Bottles stored outside of enclosed superstructure shall be fitted in a box or compartment that protects them from sea splash and mechanical damage. The box should be fitted with drain holes and the bottles should be raised at least 2 in. (5.1 cm) above the box floor. The box will be clearly marked and kept clear of obstruction (i.e. icing or piled ropes, tools, fishing gear etc.).
- Bottles employed in a fixed fire extinguishing systems shall not be counted to meet regulatory requirements for portable fire extinguishers.

Bottles are not stored in the engine room as this is the space being protected; bottles will be inaccessible in the event of fire in that space and/or damaged by the fire.

Storage in accommodation spaces is not allowed due to the inherent risk of CO_2 leakage from bottles. CO_2 at concentrations of 3 to 4% can cause increased breathing rates and headaches. Concentrations of 9% can cause disorientation, visual disturbance, ringing in the ears, tremors and loss of consciousness. At concentrations of about 20%, death can occur in 20 to 30 minutes. Sleeping crew and/or passengers in an accommodation space would be unaware of the onset of these effects. Bottle leakage at a rate that will yield concentrations causing problems should be extremely rare. However, they are possible, particularly with poorly maintained bottles.

Eliminating accommodation spaces and the engine room, there will be a limited number of spaces left on a small vessel for bottle storage within the superstructure. Some existing portable

based installations locate the bottles in the wheelhouse. This location should not be recommended due to concerns over the possibility of leakage.

Bottles used in a fixed fire extinguishing systems will be "hard-wired" into the system and not readily available for other use. These bottles should not be counted to meet other regulatory requirements (i.e. CSA-76: Small Vessel Regulations).

A given bottle weight requirement can be met with two bottles. For example, a 50 lb. system can employ to 25 lb. bottles. This arrangement may provide some space and cost advantage, however, the bottles will need to be joined in a manifold. The disadvantage is that this is a more complex system in that two discharge heads and two connections from bottle to manifold are required. Such a system will likely require more connections (elbows, tees, threaded joints) than single bottle systems and consequently a high risk of fault (pipe connections are can be a weak link in the system). Furthermore, higher internal system pressures are possible (750 psi or 5.2 MPa x 2).

7.7 Discharge Head/Release Mechanism

This section provides background and discussion regarding the release mechanism or "head" fitted to the fixed gas pressure container.

TP-11717: Standards for the Construction and Inspection of Small Passenger Ships

[20.5.1] The system shall be manually operated; however, a changeover switch may be incorporated to allow automatic operation when the vessel is in port and the propulsion machinery is not operating. The switch shall be suitably identified to show mode of operation of the system.

Nordic Boat Standard

[4.3] The extinguishing system shall be able to be released manually only. The release device shall be centrally positioned in the boat outside the engine room and the tank space and be protected against splash water and risk for unintentional release. An instruction shall be fitted at the release.

TP-4813: Schedule IV

[3.(4)] The means of control of any fixed gas fire-extinguishing system shall be readily accessible and simple to operate and shall be grouped together in as few locations as possible at positions not likely to be cut off by fire in a protected space; at each location there shall be clear instructions relating to the operation of the system having regard to the safety of personnel.

[3.(5)] Automatic release of fire-extinguishing medium shall not be permitted, except as prescribed in subsection 2(17) {automatic pressure relief in closed piping}, 7(4) {gas container pressure relief}, section 12 {automatic discharge may be considered for space that personnel visit infrequently such as unmanned machinery spaces and paint lockers}, 17(7) {pressure relief on gas bottles} and sections 18 to 20 {halon ... now banned}.

[3.(6)] Manual controls, to secure operation shall (a) require a pull of not greater than 178 N; and (b) have a travel not greater than 0.356 m.

[3.(7)] All devices shall be designed for the service they will encounter and shall not be susceptible to accidental operation.

[3.(8)] Devices shall be normally designed to function from –29°C to 66°C.

[3.(9)] All devices shall be located, installed or suitably protected so that they are not subject to mechanical, chemical, or other damage, which would render them inoperative.

[10.(1)] Subject to subsection (2) {below} provision shall be made to release the carbon dioxide by two separate means, one of which shall be an emergency manual control, which shall be easily accessible and located close to the valves controlled; if the normal manual control meets the conditions for the emergency manual control then the normal control may suffice.

[10.(2)] Where gas pressure from pilot cylinders fed through the system discharge manifold (i.e. using back pressure rather than a separate pilot line) is used as a means for releasing the remaining slave cylinders, not less than two pilot cylinders shall be used for systems consisting of more than two cylinders; except as otherwise required by 12(5) {automated systems for infrequently occupied spaces}, each of the pilot cylinders shall be capable of manual control at the cylinders, but the remaining cylinders need not be capable of individual manual control; the supply and discharge rate from the system or pilot cylinders shall be designed for releasing all the remaining cylinders and where two or more pilot cylinders are used the release system shall be operable with one pilot cylinder inoperative.

[10.(4)] In machinery spaces, the arrangements of the fire extinguishing system shall permit the whole charge of gas to be released simultaneously into the space protected.

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[4.1.11] The means of control of any fixed gas fire-extinguishing system are to be readily accessible and simple to operate and shall be grouped together in as few locations as possible not likely to be cut off by a fire in a protected space. At each location there are to be clear instructions relating to the operation of the system having regard to the safety of personnel.

[4.1.12] Automatic release of fire-extinguishing medium is not permitted.

Guidelines

The excerpts above are concerned with discharge head design and operating requirements. If the standards accept only "approved" discharge heads; as will be equipped with approved portable extinguishers, then technical details may be dispensed with in the Standard. However, the following points should be made in the Standard:

- Discharge heads will be ULC, UL or equivalently approved and marked thus,
- Discharge heads will not be modified in any manner.

7.8 System Piping

The following sections provide background and discussion regarding the various components of the fixed gas distribution systems, including:

- Piping
- Hangers and Bracing
- Expansion Joints

On large vessel installations, valves are an issue of concern as typically several compartments may be served by the same bank of cylinders. These compartments may be isolated using valves. For the small vessels of interest to this study, no need for valves in the gas distribution system is foreseen; one compartment (engine room) protection.

Guidelines

The primary concerns regarding piping are:

- Ability to evenly distribute gas within the compartment being protected,
- Ability to withstand system pressure,
- Corrosion resistance,
- Fire resistance, and
- Sufficient support (hangers) to withstand "kick-back" during gas release.

Experts in piping systems design may readily calculate system pressure and losses through pipe runs and connections and then optimise piping schedules (based on burst pressure and accepted working pressure) throughout the system. For small vessels, this is deemed an overly complex methodology requiring a level of expertise not expected from vessel operators. A more practical approach is identifying the simplicity of small vessel systems (short pipe runs and number of connectors, elbows, tees etc.) and simply specifying piping that can handle expected pressures (~750 psi; some variation with temperature).

From survey work completed during this project, the piping on portable extinguisher based systems was noted as typically either household (M-grade) copper tubing, hydraulic hose or galvanized steel pipe. Copper tube should be avoided due to low bursting pressure on soldered joints and hydraulic hose should be avoided due to concerns over the possibility of heat/fire damage. Therefore, galvanized (internal and external galvanizing) or stainless steel piping is recommended. NFPA-12 identifies ASTM A-53 seamless or electric welded, Grade A or B, or ASTM A-106 Grade A, B or C galvanized black pipe or TP-304 or TP-316 stainless pipe (TP-304 L and TP-316 may be used for welded connections).

The exception to galvanized or stainless pipe is the length of hose that connects the extinguisher to the system piping. This hose should be connected to the galvanized pipe via a threaded swivel connection that can be readily disconnected to allow for bottle removal (for inspection and weighing). The hose connection from hose to pipe should be located in the same space as the bottle and not passed through a deck or bulkhead penetration.

The Standard should not be applicable to systems requiring over 100 lb. of CO_2; such systems are sufficiently complex that only professional installation by certified manufacturers representatives is recommended. By limiting system gas quantity, based on the excerpts reviewed, piping specifications can be simply stated as:

- Pipe and fittings shall have a working pressure of 3,000 [psi] (207 [bar])
- A minimum requirement for 1/2 in. diameter schedule 40 pipe.
- Pipe fittings either welded or American Standard pipe thread (NPT)
- Ferrous fittings either Class 300 malleable iron or ductile iron.
- Cast iron fittings shall not be used.
- Threaded joints to be suitably reamed and chamfered.
- After cutting, threading and reaming, pipe shall be cleaned to remove oil, lacquer, scale and cuttings using a degreasing solution run through the pipe.
- Use pipe sealant on male thread only. Joints should be tightened until engagement as noted below:

Pipe Size	1/2 in.	3/4 in.
Engagement	1/2 in.	9/16 in.

- When making welded connections, bevel type welded fittings shall be installed.
- During welding care must be taken to ensure that weld splatter and molten metal does not enter the pipe.
- Piping should be arranged to be self-draining.
- A dirt trap and capped nipple should be installed at the end of each pipe run.

The use of larger pipe sizes 1 in. and up is acceptable, however in small systems (< 100 lb. bottles) there may be some concern over reduced flow rate due to larger internal pipe area.

Manufacturers installation manuals indicate the need for an expansion joint per 100 ft. (30.48 m) run of pipe. On vessels limited to 24.4 m of length, pipe runs of this length should not exist. On small vessels where gas quantity is limited, piping runs are short and the pipe sizes are oversized (1/4 in. piping), expansion joints are deemed unnecessary.

The standards should make comment regarding hanging of the piping system. The following statements should suffice:

- Piping must be securely braced and fastened to the vessel structure.
- Piping shall not be hung or supported from other piping (i.e. water or fuel lines).
- Maximum spacing between piping support shall be as follows:

Pipe size	1/2 in.	3/4 in.
Max support spacing	5 ft.	6 ft.

Another area of concern is that of bulkhead and deck penetrations to allow the passage of system piping. Survey work shows that in some instances such penetrations are simply a hole cut larger than the pipe diameter. Such an arrangement may provide a leakage point for gas entering the space. Penetrations should be capped on either side.

For small vessel systems, there should be no requirement to block off sections of the piping distribution systems with valves. Consequently, the Standard should state that valves will not be

installed anywhere in the piping system. Such a statement will avoid the danger of a valve being inadvertently closed rendering the system inoperable.

Note should also be made that lengths of pipe shall not be left exposed to the environment (i.e. open along deck) or run through refrigerated compartments (i.e. fish hold) unless suitably insulated and protected.

7.8.1 General

TP-4813: Schedule IV

[2.(2)] The piping, valves and fittings of each system shall (a) meet the requirements of the Machinery Regulations and be made of galvanized steel or other equivalent corrosion resisting material; and (b) be properly connected and securely supported and where necessary, protected against damage.

[2.(5)] The piping for the distribution of the fire-extinguishing medium shall be arranged and discharge nozzles so positioned that a uniform distribution of medium is obtained.

[2.(9)] Where the fire extinguishing medium is provided through a common manifold, to more than one protected space, the necessary piping shall be provided with control valves so marked as to indicate clearly the spaces to which the pipes are led; control valves shall be of the quick opening type to avoid wire drawing and consequent freezing.

[2.(12)] All pipes shall be arranged to be self-draining and shall not be led through refrigerated spaces unless the pipes are specially insulated.

[2.(16)] In carbon dioxide systems the minimum bursting pressure of the piping and the fittings in installations using, (a) high pressure gas, shall be 34.5 MPa except that valves constantly under pressure shall be 41.5 MPa; and (b) low pressure gas, shall be 12.5 MPa.

[2.(17)] In systems where the valve arrangement introduces sections of closed piping. Such sections shall be protected with automatic pressure relief devices venting to a safe location which may be the approved storage space; for carbon dioxide systems these devices shall be set to relieve at; (a) between 16.5 and 20.5 MPa, in the case of high pressure systems; and (b) 3 MPa, in the case of low pressure systems.

Lloyd's Register of Shipping - Part 6, Chapter 4, Section 4 (Jan. 1998)

[4.1.2] The necessary pipes for conveying a fire-extinguishing medium into protected spaces are to be provided with control valves which are to be so placed that they will be easily accessible and not readily cut off from use by an outbreak of fire. The control valves are to be so marked as to indicate clearly the spaces to which the pipes are led. Suitable provision is to be made to prevent inadvertent admission of the medium to any space.

[4.1.3] The piping for the distribution of fire-extinguishing medium is to be of adequate size and so arranged, and discharge nozzles so positioned that a uniform distribution of medium is

obtained. A means whereby the individual pipes to protected spaces can be tested using compressed air is to be provided.

7.8.2 Piping

NFPA-12 (1993): Chapter 1 - General

[1-9.1] Pipe and Fittings. Pipe shall be of non-combustible material having physical and chemical characteristics such that deterioration under stress can be predicted with reliability. Where piping is installed in severely corrosive atmospheres, special corrosive resistant materials or coatings shall be used. Examples of materials for piping and the standards covering these materials are:
(a) Ferrous Piping. Black or galvanized steel pipe shall be either ASTM A-53 seamless or electric welded, Grade A or B, or ASTM A-106, Grade A, B, or C. ASTM-120 and ordinary cast iron pipe shall not be used. Stainless steel shall be TP-304 or TP-316 for threaded connections or TP-304, TP-316, TP-304L, or TP-316L for welded connections.
(1) In systems using high-pressure supply, 3/4 in. and smaller pipe may be Schedule 40. Pipe 1 in. through 4 in. shall be a minimum of Schedule 80. Furnace butt weld ASTM-53 pipe shall not be used.
(2) In systems using low-pressure supply, pipe shall be minimum of Schedule 40. Furnace butt weld ASTM-53 pipe may be used.

[1-9.1.1] Piping system components not specifically covered in this standard shall have a minimum burst pressure of 5000 psi (34 474 kPa) for high-pressure systems or 1000 psi (12 411 kPa) for low-pressure systems.

[1-9.1.2] Fittings. Class 150 and cast-iron fittings shall not be used.
(a) High Pressure Fittings. Class 300 malleable or ductile iron fittings shall be used through 2 in., IPS and forged steel fittings in all larger sizes. Flanged joints upstream of any stop valves shall be Class 600. Flanged joints downstream of stop valves or in systems with no stop valves may be Class 300. Stainless steel fittings shall be type 304 or 316, wrought/forged (per ASTM A-182), Class 3000, threaded or socket weld, for all sizes 1/8 in. through 4 in.

[1-9.1.3] Welded joints, screwed or flanged fittings (malleable iron or ductile iron) may be used. Mechanical grooved couplings and fittings may be used if they are specifically listed for carbon dioxide service. Flush bearings shall not be used. Where hex bushings are used, more than one pipe size reduction or a 3000 lb. forged steel bushing shall be provided to maintain adequate strength. Suitable flared, compression-type or brazed fittings shall be used with copper or brass tubing. Where brazed joints are used, the brazing alloy shall have a melting point of 1000°F (538°C) or higher.

[1-9.1.4] In systems using high-pressure supply, the piping system shall have a minimum bursting pressure of 5000 psi (34 474 kPa).

[1-9.2.1] Pipe shall be reamed and cleaned before assembly, and after assembly the entire piping system shall be blown out before nozzles or discharge devices are installed.

[3-9-2] Pipe sizes and orifice areas shall be selected based on calculations to deliver the required rate of flow at each nozzle.

[3-9-3-1] The following equation or curves developed shall be used to determine the pressure drop in the pipeline:

$Q^2 = 3667\ D^{5.25}\ V / [\ L = 0.88\ [D^{1.25}\ Z]]$

where, Q = Flow rate in lb/min
D = Inside pipe diameter (actual) in inches
L = Equivalent length of pipeline in feet
V & Z = Factors depending on storage line pressure

[3-9-3-3] For systems with high-pressure storage, flow shall be calculated based on an average storage pressure of 700 psia (4171 kPa) during discharge for normal 70°F (21°C) storage. The discharge rate through equivalent orifices shall be based on the values given in Table 3-9-8-I(c). Design nozzle pressure at 70°F (21°C) shall be not less than 300 psia (2068 kPa).

[illegible]: Chapter 2 – [illegible]

[3-9-4] Piping shall be designed in accordance with 3-9-3 to deliver the required rate of application at each nozzle.

[3-9-5] The nozzles used shall be listed or approved for rate of discharge, effective range, and pattern or area coverage.

[3-9-3-1] The equivalent orifice size used in each nozzle shall be determined in accordance with 3-9-3 to match the discharge rate.

[illegible]

[10] 20-20] Piping
(a) Branch lines to the various cargo spaces shall not be less than 1/2 in. standard pipe size.
(b) The size of branch lines to machinery and fuel tank spaces, paint lockers, oil rooms and similar hazardous spaces shall be as noted in Table 10] 20-20(b).

Table [illegible]

Maximum Quantity (Q), Required [lb.]	Maximum Pipe Size [in.]
100	1/4
250	3/8
350	1/2
400	1 1/4

(c) All piping, valves, and fittings of ferrous materials shall be protected from inside and outside against corrosion.
(d) All dead-end lines shall extend at least 2 in. beyond the last orifice and shall be closed with cap or plug.
(e) All piping, valves, and fittings shall be securely supported and where necessary protected against injury.
(f) Drains and dirt traps shall be fitted where necessary to prevent the accumulation of dirt or moisture. Drains and dirt traps shall be located in accessible locations.

[illegible] (construction and maintenance manual) Section 7

[7.2] Pipes and fittings. The following provides specifications for materials normally used. This does not preclude the use of other materials such as brass, copper, stainless steel, flexible hose, etc. provided they satisfy the system pressure/temperature requirements (working pressure of 3000 psi/207 bar). Pipe and fittings shall have a minimum bursting pressure (not working pressure) of 5000 psi/345 bar.

The project drawings will indicate the specific piping materials to be utilized for each project. As the type of piping materials to be utilized are incorporated into system flow/pressure loss design, the system designer must be contacted if materials other than those specified are used, and the designers approval must be received.

Ferrous Pipe. Seamless or electric weld, black or galvanized (galvanized is recommended) pipe conforming to ASTM A-53 or A-106, Grades A or B. ANSI B36.10.
Sizes: 1/8 in. through 1/4 in. Schedule 80 (standard). 1 in. through 8 in. Schedule 80 (extra heavy)
Cast iron pipe and pipe conforming to ASTM A-120 shall not be used.

Ferrous Fittings. Threaded 1/4 in. through 2 in. Class 300 malleable iron or ductile iron. 2 1/2 in. & larger. 3000# forged steel. Class 150 and cast iron fittings shall not be used.

[7.3] Pipe Connections. All threaded joints shall have American Standard pipe threads (NPT) in accordance with ANSI B2.1. All threads shall be full length cut be suitable reamed and chamfered. After cutting and threading, pipe shall be reamed and cleaned before assembly to remove cutting oil, burrs, scale and cuttings, using a degreasing solution run through the pipe interior.

For assembly, use pipe socket applied to male thread only. Joints should be tightened and engagement conditions in the specified for right joints using American Standard pipe threads. Nominal engagements for right joints are as follows:

Pipe size (in.)	1/4	3/8	1/2	3/4	1	1 1/4	1 1/2	2
Engagement (in.)	3/8	3/8	1/2	9/16	11/16	11/16	11/16	3/4

Welded Pipe Connections. When making welded connections, bevel type welded fittings shall be installed and all welding shall be performed in accordance with Section IX, qualification standard for welding and brazing procedures, welders, brazer operators, of the ASME boiler and pressure vessel code. During welding care must be taken to ensure that weld spatter and welding metal does not enter the pipe and that any roughness that could affect flow is removed.

Tube Connections. When using tube compression type fittings are preferred. The pressure/temperature ratings of the manufacturer of the fitting shall not be exceeded. When compression are "soldered" or "brazed" the melting point of the soldered metal should be at least (600°F).

[1.7] Changes in the piping that may be necessary, or not, the conditions can critically affect the system flow balance. Any deviation in the piping must be approved by the designer prior to field implementation.

When reducing fittings are called for on the installation drawings, brought bushings made of forged steel should be used. Whenever bushings reducing 3 fittings may also be used provided they with the correct pressure/temperature ratings are stamped. Solder on caulkings shall. Such bushings or cast iron bushings be allowed. If face reducing fittings are required to make the necessary reductions, they shall be chosen as right the reductions specify.

Y-dirt cup and thermos consisting of y-in. with a capped nipple 3 in. in 6 in. (76 in. 15 mm) long. should be installed a the end of each pipe run.

Piping through walls. Every air, shall be run through sleeves of Schedule 40 pipe or larger size when larger than the pipe being run and not smaller than one in. Sleeves through floor slabs shall extend at least 3 in. (1 1 mm) above the floor. Sleeves shall be packed with the material required in the best and weather right, as specified in project drawings.

Guide Pipe Systems - Design, Installation, Operation and Maintenance Manual, Part 0

[1.1] The piping between the cylinder and nozzles must be the shortest route possible with a minimum of fittings. Any deviation in the routing or number of fittings must be approved by the design engineer prior to installation.

Piping and tubing must be routed free of flares and edges after cutting, welding or bending. All threaded joints must conform to ANSI B1.20.1. Joint compound tape or thread sealant must be applied only to the male threads of the joint, excluding the first two threads. Welding must be in accordance with Section IX of the ASME Boiler and Pressure Vessel Code. Each pipe section must be established clean, using a non-flammable organic solvent.

All piping must be blown out with nitrogen, carbon dioxide, or compressed air prior to installing the discharge nozzles. Dirt traps must be installed at the end of each nozzle header, or branch line.

NFPA-12, Sub-section 1-10.1, states "Piping shall be of non combustible material having physical and chemical characteristics such that its deterioration under stress can be predicted with reliability. Special corrosion resistant materials or coatings may be required in severely corrosive atmospheres. Examples of materials for piping and the standard covering these materials are:
(a) Ferrous Piping: Black or galvanized steel pipe shall be either ASTM A-53 seamless or electric welded, Grade A or B, or ASTM A-106, Grade A,B, or C. ASTM A-120 and ordinary cast iron pipe shall not be used.
1.) In systems using high-pressure supply, 3/4 in. and smaller pipe may be Schedule 40. Pipe 1 in. through 8 in. shall be a minimum of Schedule 80. Furnace butt weld ASTM-53 shall not be used.
2.) In systems using low-pressure supply, pipe shall be a minimum of Schedule 40. Furnace butt weld ASTM-53 pipe may be used.

(b) This standard does not preclude the use of other piping materials such as stainless steel or other piping or tubing pro-vided, for high pressure supply, an internal pressure of 3000 psi (20.7 MPa), and for low pressure supply, an internal pressure of 450 psi (3.1 MPa), which will not cause material stress greater than the material's yield point when calculated according to ANSI B-31.1, Power Piping Code.

NFPA-12, Sub-section 1-10.1.2, states "Class 150 and cast iron fittings shall not be used. (a) High Pressure Fittings: Flanged joints upstream of any stop valves or in systems with no stop valves may be Class 300. Flanged joints shall be Class 600."

NFPA-12, Sub-section A-10.2.1, states "A dirt trap consisting of a tee with a capped nipple at least 2 in. (51 mm) long, should be installed at the end of each pipe run."

NFPA-12, Sub-section 1-10.1.4, states "In systems using high pressure supply, the piping system shall have a minimum bursting pressure of 5000 psi (413.7 bars)."

NFPA-12, Sub-section 1-10.2.3, states "Pipe shall be reamed and cleaned before assembly, and after assembly the entire piping system shall be blown out before nozzles or discharge devices are installed."

Lloyd's Register of Shipping - Part 6, Chapter 4, Section 4 (Jan. 1998)

[4.1.4] Steel pipes fitted in spaces where corrosion is likely to occur are to be galvanized, at least externally.

[4.1.5] Distribution pipes are not to be smaller than 20 mm bore for carbon dioxide.

7.0.5 Hangers and Bracing

NFPA-12 (1993): Chapter 1 - General

[1-9.2] The piping system shall be securely supported with due allowance for agent thrust forces, thermal expansion and contraction, and shall not be subject to mechanical, chemical or other damage. Where explosions are possible, the piping system shall be hung from supports that are least likely to be displaced.

SEA-CLEAR FIRE Installation and maintenance manual: Section 5

[5.4] All system piping, both vertical and horizontal, must be suitably supported with hangers conforming to the latest requirements of ANSI B31.1.

Pipe hangers shall be capable of supporting the pipe under all conditions of operation and service. They shall allow for the expansion and contraction of the piping, and shall prevent pipe loads and stresses from being transmitted into connected equipment. Hangers and supports shall be of rugged design and shall be installed so that they will not be loosened by movement of the supported pipe. "U"-bolts with double nuts should be used.

Pipes must be braced or anchored to the building structure such as beams, columns, concrete walls, etc., in order to prevent longitudinal and lateral movement and sway. Carbon dioxide piping must not be hung or supported from other piping systems (i.e., water, compressed air, etc.).

Large forces are exerted on the system cylinder(s) and piping during discharge. Each section of pipe must be braced or secured to restrict both the vertical and lateral movement. Where practical, riser piping shall be supported independently of the connected horizontal piping. A support must be installed adjacent to each discharge nozzle and wherever a change in pipe direction occurs.

In addition, for some regions classified as earthquake zones, or for projects such as nuclear sites subject to unique code requirements, special sway bracing and/or hangers maybe required. Refer to the project and/or contract drawings for requirements of special bracing.

Generally, no section of pipe should be without a hanger or brace. Maximum spacing between hangers and hanger rod sizes shall be as indicated below, which are in accordance with ANSI B31.1.0.

Pipe Size [in.]	1/2	3/4	1	1 1/4	1 1/2	2	2 1/2	3
Max. Spacing [ft.]	5	6	7	9	9	10	11	12

Pipe Size	Rod Size
1/2 in. to 2 in. inclusive	3/8 in.
2 1/2 in. to 3 1/2 in. inclusive	1/2 in.

Kidde Fire Systems - Design, Installation, Operation and Maintenance Manual, Part 5

[5.2] The piping system must be securely braced to account for discharge reaction forces and thermal expansion/contraction. Care must be taken to insure that piping is not subjected to vibration, mechanical, or chemical damage. Refer to ANSI B-31.1 for additional bracing requirements.

7.8.4 Expansion Joints

SES-CEASE FIRE installation and maintenance manual: Section 5

[5.5] A certain amount of contraction can occur, which is caused by a maximum temperature change in long continuous pipe runs. Approximately 1 in. per 100 ft. (2.54 cm per 30.48 m) of steel pipe. Often, as part of the natural layout of the system, a swing joint can serve to give the desired flexibility. In straight runs, an expansion joint shall be installed on the basis of one after approximately 100 ft. (30.48 m) of continuous run and after each 100 ft. (30.48 m) run thereafter.

7.9 Discharge Nozzles

This section provides background and discussion regarding the discharge nozzles.

NFPA-12 (1993): Chapter 1 - General

[1-9.4] Discharge Nozzles. Discharge nozzles shall be suitable for the use intended and shall be listed or approved for discharge characteristics. The discharge nozzle consists of the orifice and any associated horn, shield, or baffle.

[1-9.4.1] Discharge nozzles shall be of adequate strength for use with the expected working pressures, be able to resist nominal mechanical abuse, and be constructed to withstand expected temperatures without deformation.

[1-9.4.2] Discharge orifices shall be corrosion resistant metal

[1-9.4.4] Discharge nozzles shall be permanently marked to identify the nozzle and to show the equivalent single orifice diameter regardless of shape and number or orifices. This equivalent diameter shall refer to the orifice diameter of the standard single orifice type nozzle having the same flow rate as the nozzle in question. The marking shall be readily discernible after installation. The standard orifice is an orifice having a rounded entry with a coefficient of discharge not less than 0.98 and flow characteristics as given in Tables 1-9.4.4(b) (low pressure) and 1-9.4.4(c)

[1-9.4.5] Discharge nozzles shall be provided with frangible discs or blow out caps where clogging by foreign materials is likely. These devices shall provide an unobstructed opening upon system operation.

[1.9.5] Pipe sizes and orifice areas shall be selected based on calculations to deliver the required rate of flow at each nozzle.

[1-9.5.3] For systems with high-pressure storage, flow shall be calculated based on an average storage pressure of 750 psia (5171 kPa) during discharge for normal 70°F (21°C) storage. The discharge rate through equivalent orifices shall be based on the values given in Table 1-9.4.4(c). Design nozzle pressure at 70°F (21°C) shall be not less than 300 psia (2068 kPa).

Table 1-9.4.4(c)
Discharge Rate per Square In. of Equivalent Orifice Area for High Pressure Storage [750 psia (5171 kPa)]

Orifice Pressure [psia]	Discharge Rate [lb./min/sq. in.]
750	4630
725	3845
700	3415
675	3090
650	2835
625	2615
600	2425
575	2260
550	2115
525	1985
500	1860
475	1740
450	1620
425	1510
400	1400
375	1290
350	1180
325	1080
300	980

Table 1-9.4.4 (a)
Equipment Orifice Sizes

Orifice Code [#]	Equivalent Single Orifice Diameter [in.]	Equivalent Single Orifice Area [sq. in.]
1	1/32	0.0008
1.5	3/64	0.0017
2	1/16	0.0031
2.5	5/64	0.0047
3	3/32	0.0069
3.5	7/64	0.0094
4	1/8	0.0123
4.5	9/64	0.0155
5	5/32	0.0192
5.5	11/64	0.0232
6	3/16	0.0276
6.5	13/64	0.0324
7	7/32	0.0376
7.5	15/64	0.0431
8	1/4	0.0491
8.5	17/64	0.0554
9	9/32	0.0621
9.5	19/64	0.0692
10	5/16	0.0767
11	11/32	0.0928
12	3/8	0.1105
13	13/32	0.1296
14	7/16	0.1503
15	15/32	0.1725
16	1/2	0.1964
18	9/16	0.2485
20	5/8	0.3068
22	11/16	0.3712
24	3/4	0.4418
32	1	0.7850
48	1-1/2	1.7650
64	1	3.1400

NFPA-12 (1993): Chapter 2 - Total Flooding Systems

[3.6.3] The nozzles used shall be listed or approved for rate of discharge, effective range, and pattern or area coverage.

[3-6.3.1] The equivalent orifice size used in each nozzle shall be determined in accordance with 1-9.5 to match the discharge rate.

46 CFR, Subchapter T

[181.20-25] Discharge Outlets
(a) Discharge outlets shall be of an approved type.
(b) The total area of all discharge outlets shall not exceed 85% nor be less than 35% of the nominal cylinder outlet area, or the area of the supply pipe, whichever is smaller. The nominal cylinder outlet area in square in. shall be determined by multiplying the factor 0.0022 by the number of pounds of carbon dioxide required except that in no case shall this outlet area be less than 0.110 sq. in. (0.71 cm^2)

SES-CEASE FIRE installation and maintenance manual: Section 5

[5.7 (4)] For total flooding applications, nozzles should be located at the highest practical elevation within the enclosure. Except where more than one tier of nozzles is used, or special application conditions apply, the bottom of the orifice should not be more than 12 in. (30.48 cm) from the top of the enclosure.

[5.7 (5)] There must not be any obstructions adjacent to the nozzles (structural columns or beams, ducts, cable trays, racks, equipment, etc.) that will affect the discharge patterns or dispersement of carbon dioxide.

KIDDE design, installation, operation and maintenance manual: part 3

[3.2.5.4] Discharge Nozzles: For total flooding of rooms and large enclosures, the types "S" and "M" multi-jet nozzles are generally used. For total flooding of ducts and small enclosure, the smaller type "V" nozzle may be used.

The number of nozzles required depends on the following considerations:
1. Maximum Spacing: Use 20 foot spacing, as a guide.
2. Flow Rate: The 1/2 in. "S" and "V" nozzles will handle up to 120 lb./min/nozzle (54 kg/min/nozzle). Use 3/4 in. "M" nozzle for flow rates in the range 121 to 250 lb./min/nozzle (55 – 113 kg/min/nozzle).
3. Obstructions: If obstructions within the protected space interfere with the efficient distribution of carbon dioxide, or lower nozzle flow rates are desired, it may be necessary to increase the quantity of nozzles initially arrived at when using the maximum spacing and flow rate guidelines.

Guidelines

Some of the problems being addressed (i.e. Materials of construction, markings) in the excerpts above may be avoided by insisting that discharge nozzles be approved by ULC, UL or equivalent. The standards should make comment regarding the number of nozzles and placement.

Nominal bottle cylinder outlet area is calculated by multiplying the bottle gas weight by the factor 0.0022. If there is more than one bottle in the system, gas weight of each bottle is added to get total system gas weight. However, in no case shall the number calculated be less than 0.110 sq. in. Thus for all standard size portable extinguishers (10, 15, 20, 25, 30, 35, 40 and 50 lb.) an outlet area of 0.110 sq. in. (0.71 cm^2) is assumed.

The total orifice outlet area of discharge nozzles shall not exceed 85% or be less than 35% of the nominal cylinder outlet area (0.110 sq. in. or 0.71 cm^2). It is not foreseen that any small vessel system would require more than four (4) nozzles; most would be equipped with one or two only. Based on these criteria, the table noted below may be derived for use in the standard:

Acceptable System Nozzles

Discharge Nozzle Orifice Code	Number of Nozzles in System			
	1	2	3	4
4				*
4.5			*	*
5		*	*	*
5.5	*	*	*	*
6	*	*	*	
6.5	*	*		
7	*	*		
7.5	*	*		
8	*			
8.5	*			
9	*			
9.5	*			
10	*			
11	*			

In addition to the table above, the following notes, derived directly from the excerpts reviewed should be included in the standard:

- Discharge nozzles shall be of an approved type; UL, ULC or equivalent.
- Nozzles should be of the "S" type.
- Nozzles should be so arranged to provide an even distribution of gas within the engine room.
- Nozzles should be located as high as possible within the space.
- Nozzles should be positioned so that the markings can be easily seen.
- There should not be any obstructions adjacent to the nozzles (i.e. piping, beams, equipment etc.).
- Nozzles should not be placed adjacent to vents, dampers or fans.

7.10 Detection and Alarm

This section provides background and discussion regarding fire detection and alarm systems.

TP-4813: Schedule IV

[4.(1)] Means shall be provided for automatically giving audible warning and where noise level is near or above the audible signal, there shall also be visual warning of the release of fire-extinguishing medium into any space in which personnel normally work or have access.

[4.(2)] The alarms shall operate for a suitable period of time before the medium is released, depending on size and configuration of space and to allow for the effective automatic shutdown of machinery and equipment as considered necessary by the requirements of 3(1) {venting or other machinery that could sustain fire}.

[4.(3)] The time delay shall be automatic or manual depending on type of system and the size and configuration of space.

[4.(4)] The alarms shall function to warn against personnel entry into a hazardous space as long as such hazards exist or until such hazards are properly recognized; the alarms shall be distinctive from other signals transmitted to the protected space.

[4.(5)] Gas operated alarms shall not be tested by means of the extinguishing medium.

[4.(6) Pneumatically operated alarms may be used, provided that air supply is clean and dry.

Lloyd's Register of Shipping - Part 6, Chapter 4, Section 4 (Jan. 1998)

[4.1.8] Means are to be provided for automatically giving audible warning of the release of fire-extinguishing medium into any space in which personnel normally work or to which they have access. The alarm is to operate for a suitable period before the medium is released.

[4.1.9] Where pneumatically operated alarms are fitted which require periodic testing, carbon dioxide is not to be used as an operating medium. Air operated alarms may be used provided that the air supply is clean and dry.

[4.1.10] Where electrically operated alarms are used, the arrangements are to be such that the electric operating mechanism is located outside the pump room.

SOLAS - Chapter II-2, Regulation 5

[1.6] Means shall be provided for automatically giving audible warning of the release of fire-extinguishing medium into any space in which personnel normally work or to which they have access. The alarm shall operate for a suitable period before the medium is released.

Guidelines

There are two aspects of the guidelines that may be problematic:

- Human exposure to even small concentrations of CO_2 is hazardous (discussed in Section 2.6). Pre-discharge alarm on large vessel systems is a requirement. However, on small vessels, engine rooms are small and not typically manned. Furthermore, the number of personnel onboard is limited. These facts may give argument that no alarm system is necessary.

- Detection on small vessels depends on the watch. Smoke detection in small engines is likely impractical, in small engine rooms normal operating exhausts will likely result in continuous activation. Heat detectors are more practical however, they can be costly.

It is suggested that the Standard need not include a requirement for detection and alarm. However, note should be made regarding operating instructions to be posted adjacent to the bottles. The operating instructions should indicate that all personnel be accounted for before discharge; this is not an unrealistic requirement on a vessel of 24.4 m length or less.

7.11 Miscellaneous Design Considerations

This section provides background and discussion regarding a number of miscellaneous design issues not covered by other sections.

NFPA-12 (1993): Chapter 1

[1-5.1, 1.5.1.1] Discharge of CO_2 in fire extinguishing concentration creates serious hazards to personnel, such as suffocation and reduced visibility during and after discharge. Consideration shall be given to the possibility of carbon dioxide drifting and settling into adjacent places outside of the protected space. Consideration also to be given to CO_2 discharge from safety release valve of cylinder.

Nordic Boat Standard

[4.8] The engine room and spaces for carbon dioxide bottles and other parts of the system where leakage can occur shall be separated in such a way that leaking gas cannot penetrate into spaces for personnel which can be closed. Spaces for bottles shall have ventilation direct to open air.

Lloyd's Register of Shipping - Part 6, Chapter 4, Section 4 (Jan. 1998)

[4.1.1] The use of a fire-extinguishing medium that, either by itself or under expected conditions of use, gives off toxic gases in such quantities as to endanger persons is not permitted.

TP-4813: Schedule IV

[2.(7)] Electrostatic charging of non-grounded conductors may occur during the discharge of liquefied gases, therefore where fire extinguishing systems protect areas where explosive atmospheres could exist, measures shall be taken to prevent electric arcing.

[2.(18)] Spare parts for the system shall be stored on board as recommended by the manufacturer and shall be specified on plans.

[2.(8)] The discharge of fire-extinguishing medium into a space shall not endanger personnel engaged in operation and maintenance of equipment or using normal access ladders and escape facilities serving the space.

Guidelines

These primary concern of the excerpts noted above is the fact that CO_2 is hazardous to personnel. This fact may not be common knowledge and should be emphasized within the standards.

7.12 Inspection and Testing

This section provides background and discussion regarding inspection and testing of fixed fire extinguishing systems.

NFPA-12 (1993): Chapter 1 - General

[1-10.1] Inspection. At least every 30 days, an inspection shall be conducted to assure the system operational condition.

[1-10.2] Testing. All system hoses including those used as flexible connectors shall be tested at 2500 psi (17 239 kPa) for high-pressure systems, and at 900 psi (6205 kPa) for low-pressure systems. Hoses shall be tested as follows:
(a) Remove the hose from any attachment.
(b) Hoses for hand lines shall be checked for electrical continuity between couplings.
(c) The hose assembly shall then be placed in a protective enclosure designed to permit visual observation of the test.
(d) The hose shall be completely filled with water before testing.
(e) Pressure shall then be applied at a rate of pressure rise to reach the test pressure within one minute. The test pressure shall be maintained for one full minute. Observations shall then be made to note any distortion or leakage.
(f) If the test pressure has not dropped and if the couplings have not moved, the pressure shall be released. The hose assembly shall then be considered to have passed the hydrostatic test if no permanent distortion has taken place.
(g) Hose assembly passing the test shall be completely dried internally. If heat is used for drying, the temperature shall not exceed 150°F (66°C).
(h) Hose assemblies failing the above tests shall be marked and destroyed. They shall be replaced with new assemblies.
(i) Hose assemblies passing the test shall be suitably marked with the date of the test on the hose.

[1-10.2.1] All system hoses including those used as flexible connectors shall be tested every five years in accordance with 1-10.2.

[1-10.3.1] A manufacturer's test and maintenance procedure shall be provided to the owner for testing and maintenance of the system. This procedure shall provide for the initial testing of the equipment as well as for periodic test inspection and maintenance of the system.

[1-10.3.2] At least annually, all carbon dioxide systems shall be thoroughly inspected and tested for proper operation by competent personnel.

[1-10.3.2.1] The goal of this inspection and testing shall be not only to ensure the system is in full operating condition, but shall indicate the probable continuance of that condition until the next inspection.

[1-10.3.2.2] Suitable discharge tests shall be made when any inspection indicates their advisability. Prior to testing, proper safety procedures shall be reviewed.

[5-10.3.3] An inspection report with recommendations shall be filed with the owner.

[5-10.3.4] Between the regular service contract inspection or tests, the system shall be inspected visually or otherwise by approved competent personnel, following an approved schedule.

[5-10.3.5] At least semi-annually, all high-pressure cylinders shall be weighed and the date of the last hydrostatic test noted. If, at any time, a container shows a loss of more than 10%, it shall be refilled, unless the minimum gas requirements are still provided.

[5-10.3.7] Testing of heat, smoke and flame detectors shall be in accordance with NFPA 72®, Standards on Automatic Fire Detectors, Section 6-3.

[5-10.3.8] The system shall be kept in full operating condition at all times. Use, impairment, and restoration of fire protection shall be reported promptly to the authority having jurisdiction. Any troubles or impairments shall be corrected at once by competent personnel.

[5-10.4] Instruction. Persons who inspect, test, maintain, or operate carbon dioxide fire extinguishing systems shall be thoroughly trained in the functions they perform.

5-10.5 Acceptance Test

[5-10.5] Upon completion of the piping installation and before the gas containers are connected, pressure tests using dry air, nitrogen, or suitable inert gas shall be carried out as follows:
(a) for high-pressure installations:
(1) the piping from the containers to the stop valves in the manifold shall be subjected to a pressure of 7 MPa for CO_2 systems and the test shall demonstrate that with no additional gas being introduced, the pressure drop due to gas leakage shall not be more than 1 MPa per minute for a two-minute period; and
(2) the piping from the stop valves in the manifold to the spaces protected shall be subjected to a pressure of 4 MPa for CO_2 systems and the test shall demonstrate that with no additional gas being introduced, the pressure drop due to gas leakage shall not be more than 700 kPa per minute for a two-minute period. For the purpose of this test the distribution piping shall be valved off or capped within the protected space at the first joint ahead of the diffuser nozzles.
(3) in the case of small independent installations serving such spaces as pump rooms, hazardous storerooms and similar spaces, the system may be tested by blowing out the piping with air at a pressure of at least 700 kPa.

[5-10.5] Upon completion of the pressure tests, the inspector shall be satisfied that all plugs and blank flanges used during the tests have been removed from the distribution system and that all pipes are clear and correctly connected according to the markings on the distribution valve chart.

Guidelines

Inspection and testing are also areas of the standard that may prove problematic. Piping sizes and distribution design can easily be specified, however, the quality of workmanship in fabrication (i.e. welding etc.) is difficult to regulate. The proof of quality work is passing a system pressure

test. However, spill testing requires a level of expertise that will be costly compared to the system cost itself.

Portable extinguishers will be subject to existing inspection regulations. However, as with liquids, finding extinguishers in service that are not current with their inspections is not uncommon.

6. [illegible]

This $5{,}000\text{-gal}$ vessel contains an 18ft. by 50ft[illegible] reinforced to install Stand (OI). An corresponding system on their vessels in accordance with the Transport Canada specification "ANNEX [illegible] Installation, Inspection and Maintenance Manual" reproduced in Appendix C. [illegible] section of the report describes the installation on these two vessels and discusses the results obtained when the systems were tested.

6-1 [illegible]

[illegible] regulation II

The first vessel tested was the fishing vessel *[illegible] regulation II*. This is a 59.5- [illegible] no [illegible] [illegible] vessel with a gross registered tonnage of 99. It has a single diesel engine located in an aft compartment forward of the [illegible] and below the [illegible]. The engine compartment is approximately 9 ft. [illegible] long, 6 ft 6 in. [illegible] and 5 ft. 6 in. deep, giving a total volume of 365 cu. ft. [illegible] m³). Using the calculation methodology for the required OI[illegible] capacity from Appendix V, gives:

$$\text{[illegible]} = 365 \times [\text{illegible}]\ \text{lit.}$$

This is slightly in excess of the coverage allowed by the 5- [illegible] cylinder unit therefore a small watertight compartment of 11 cu. ft. [illegible] m³) was built in the engine compartment to reduce the volume to the maximum allowable for a 20 lb. cylinder.

$$\text{[illegible]} = [\text{illegible}] \times [\text{illegible}]\ \text{lit.}$$

The primary and reserve OI[illegible] for the Stand OI[illegible] system fitted on the *[illegible] regulation II* are located in a steel compartment built in the starboard after corner of the [illegible] as generally shown in Figure 6-1. This compartment is separated via a gas-tight bulkhead from the [illegible] and a provided with access via the after deck. The primary and reserve OI[illegible] cylinders are both connected to the gas discharge piping via a double valve. The gas discharge piping, a 1[illegible] galvanized steel schedule 40 piping with class 300 fittings and is led from the OI[illegible] compartment through the bulkhead of the engine compartment such that is the wood sometimes where it terminates in a discharge nozzle. The length of the discharge piping is approximately [illegible] ft. ([illegible] mm) and each contains three 90° elbows.

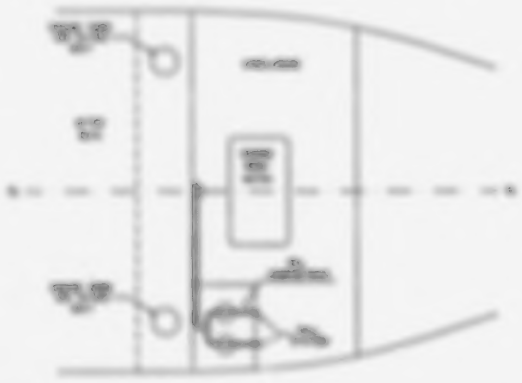

**Figure 9.1 – CO_2 Installation on the *Lexpedition II*

Manual pull stations for the gas release are located on the forward bulkhead of the CO_2 compartments within the Wheelhouse. Engine compartment air intakes, located in the port and starboard after corners of the compartment, were both fitted with closing flaps as part of the CO_2 installation. These flaps are activated via a system of cables and pulleys led to the Wheelhouse. A complete list of material provided by ANSUL for the installation is reproduced in Table 9.1.

Table 8.1 – ANSUL Components for the CO_2 Installation on *L'expedon II*

Component Name	Component Number	Quantity
20 lb. CO_2 Cylinder Shipping Assembly	427455	2
20 lb. Bracket Shipping Assembly	25420	2
Cylinder Valve Actuator	427675	2
12 in Discharge Hose	427267	2
Shuttle Valve	427266	1
Brass Pulley Elbow	45515	2
Discharge Nozzle	426120-3.5	1
Manual Pull Station	54011	2
Flared End Fitting	40060	2
Split Bold Connector	24920	2
Placard	427516	
Pressure Switch	46250	0
Pressure Trip	5156	
Manual Pull Box – Latched Door Type, Brass	45062	
Replacement Break Rod (10) for Pull Station	24915	

N/M *François Michel*

The second vessel tested was the fishing vessel *François Michel*. This is a fibreglass-hulled vessel with a gross registered tonnage of 14. It has a single diesel engine located in its own compartment forward of the hold and below the Wheelhouse. The engine compartment is approximately 7.6 ft. (2.3 m) long, 13 ft. (4 m) wide and 4 ft. (1.2 m) deep giving a total volume of 395 cu. ft. (11.2 m^3). Using the calculation methodology for the required CO_2 capacity from Appendix A gives:

$$0.0444 \times 395 = 17.54 \text{ lb.}$$

This is above the capability of a 15 lb. cylinder but well within the coverage allowable for a 20 lb. cylinder.

The primary and reserve CO_2 cylinders for the fixed CO_2 system fitted on the *François Michel* are located in an existing deck locker on the port after face of the Wheelhouse as generally shown in Figure 8.2. This compartment is accessed via a door opening onto the after deck. The primary and reserve CO_2 cylinders are both connected to the gas discharge piping via a shuttle valve. The gas discharge piping is 1 2-in. galvanized steel schedule 40 piping with class 300 fittings and is led from the CO_2 compartment through the deckhead of the engine compartment and then to the vessel centerline where it terminates in a discharge nozzle. The length of the discharge piping is approximately 12 ft. (30.48 cm) and contains five 90° elbows.

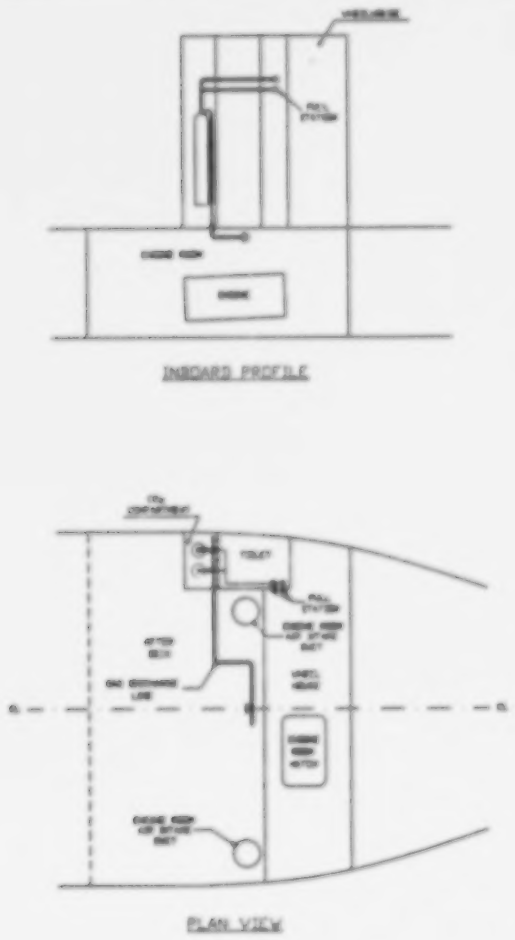

Figure 8.2 – CO_2 Installation on the *François Michel*

Manual pull stations for the gas release are located on the forward bulkhead of the CO_2 compartment within the Wheelhouse. Engine compartment air intakes, located in the port and starboard after corners of the compartment, were both fitted with closing flaps as part of the CO_2 installation. These flaps are activated via a system of cables and pulleys led to the Wheelhouse. A complete list of material provided by ANSUL for the installation is reproduced in Table 8.2.

Table 8.2 – ANSUL Components for the CO_2 Installation on *François Michel*

Component Name	Component Number	Quantity
20 lb. CO_2 Cylinder Shipping Assembly	427455	2
20 lb. Bracket Shipping Assembly	25420	2
Cylinder Valve Actuator	427675	2
12 in Discharge Hose	427267	2
Shuttle Valve	427266	1
Brass Pulley Elbow	45515	8
Discharge Nozzle	426120-3.5	1
Manual Pull Station	54011	2
Flared End Fitting	40060	2
Split Bold Connector	24920	2
Placard	427516	
Pressure Switch	46250	0
Pressure Trip	5156	0
Manual Pull Box – Latched Door Type, Brass	45062	
Replacement Break Rod (10) for Pull Station	24915	

8.2 Testing and Test Results

Tests on both vessels were carried out on May 22, 2002 on Isle de-Madeleine. Weather was clear and sunny with a temperature of about 15°C and light winds. ANSUL provided a recently calibrated three-channel gas concentration recorder for the tests however, it was discovered that one of the three channels was providing a very faint trace on the recording paper and for the first set of tests on *L'espadon* this trace was unreadable.

N/M *L'espadon II*

Tests on the *L'espadon II* were initiated by carrying out a survey of the installation for compliance with the guidelines. The CO_2 bottles, shuttle valve, system discharge piping and engine compartment vent closure were all found to have been installed correctly. The volume of the engine compartment was checked by measurement and found to consistent with the estimate made by the owner prior to the installation. The CO_2 bottle to be used for the test was temporarily removed from the system, weighed to ensure that it was full and then reconnected.

Three small bore open ended plastic tubes were located at various locations in the engine compartment. These were led through the engine compartment hatch, through the Wheelhouse door and were connected to the gas concentration recorder, which was located on the after deck. The engine compartment hatch was replaced, taking care not to disrupt the flow of air through the tubing, and the engine compartment air supply closure flaps were activated remotely from the Wheelhouse.

With the compartment sealed the previously weighed CO_2 cylinder was discharged, from the pull station, into the engine compartment and the resulting gas concentration measured over time. The following results were recorded:

Weight of full CO_2 bottle	53 lb. (24.0 kg)
Weight of bottle after discharge	34 lb. (15.4 kg)
Time to discharge	Approximately 150 seconds
Maximum Concentration of CO_2 in Engine Compartment	Sensor 1: 35%
Maximum Concentration of CO_2 in Engine Compartment	Sensor 2: 34%
Maximum Concentration of CO_2 in Engine Compartment	Sensor 3: no reading (failed to read)

Sensor	Concentration Over Time						
	30 sec	1 min	3 min	5 min	7 min	9 min	9.5 min
1	32%	35%	33%	31%	28%	25%	Compartment
2	32%	34%	33%	31%	28%	25%	Opened
3	-	-	-	-	-	-	-

N/M François Michel

Tests on the *François Michel* were initiated by carrying out a survey of the installation for compliance with the guidelines. The CO_2 bottles, shuttle valve, system discharge piping and engine compartment vent closure were all found to have been installed correctly. The volume of the engine compartment was checked by measurement and found to consistent with the estimate made by the owner prior to the installation. The CO_2 bottle to be used for the test was temporarily removed from the system and weighed to ensure that it was full. This exercise showed that the bottle had in fact been discharged and it was therefore replaced with a new bottle.

Three small bore open ended plastic tubes were located at various locations in the engine compartment. These were led through the engine compartment hatch, through the Wheelhouse door and were connected to the gas concentration recorder, which was located on the after deck. The engine compartment hatch was replaced, taking care not to disrupt the flow of air through the tubing, and the engine compartment air supply closure flaps were activated remotely from the Wheelhouse.

With the compartment sealed the previously weighed CO_2 cylinder was discharged, from the pull station, into the engine compartment and the resulting gas concentration measured over time. The following results were recorded:

Weight of full CO_2 bottle	54 lb. (24.5 kg)
Weight of bottle after discharge	34 lb. (15.4 kg)
Time to discharge	Approximately 150 seconds
Maximum Concentration of CO_2 in Engine Compartment	Sensor 1: 49%

Maximum Concentration of CO_2 in Engine Compartment Sensor 2: 51%
Maximum Concentration of CO_2 in Engine Compartment Sensor 3: 48%

Sensor	Concentration Over Time						
	30 sec	1 min	3 min	5 min	7 min	9 min	10 min
1	40%	49%	49%	49%	49%	48%	Compartment Opened
2	42%	50%	50%	49%	48%	47%	
3	40%	48%	48%	48%	47%	46%	

8.3 Analysis of Results

- The tests results indicated that the CO_2 systems on both vessels operated as predicted and provided a sufficient concentration of CO_2 within the engine compartments to extinguish a fire (concentrations required are greater than 28%).
- As expected the tests showed a far greater concentration of CO_2 on the *François Michel* due to the fact that this vessel had a far smaller engine compartment with the same gas input. The *L'espadon II* was in fact right at the limit of the 20 lb. CO_2 bottle in terms of its engine compartment volume and this is reflected in the results obtained.
- The tests indicated that the dispersion of CO_2 within the engine compartments was very uniform with very little difference in the concentration recorded on each senor.
- The results indicated that on the vessels tested there was only a slight leakage of CO_2 over time, but with the leakage on the *L'espadon II* being slightly more pronounced than that on the *François Michel*. This was partially attributed to a fairly large deckhead opening around the engine exhaust pipe on the *L'espadon II*.
- Weighing the bottles before and after the tests indicated that the full 20 lb. (9.1 kg) of gas was released on the *François Michel* whereas only 19 lb. (8.6 kg) was released on the *L'espadon II*. This was possibly a result of the scales being used to measure the cylinders or could have been the result of the bottle on the *L'espadon II* being not quite full (bottle had been installed in the spring of 2001, over a year before the tests were carried out. The bottle on the *François Michel* was new for the test).

9. CONCLUSIONS

Numerous small vessel owners have fabricated their own homemade systems based on portable extinguishers. This practice is a result of both the unavailability of very small volume ULC-approved fixed systems and the relatively high cost of the low volume systems that are available.

Regulatory authorities have concerns regarding the safety of homemade systems and as such, require guidelines for surveying vessels with homemade systems onboard. Regulatory authorities also desired the development of a ULC-approved small volume fire extinguishing system.

There are approximately 112 600 commercial small vessels either "registered" or "licensed" in Canada. It may be estimated that 90% of these have engine spaces that could be serviced by small volume fixed CO_2 fire extinguishing systems. Since many small vessels have systems for safety and insurance purposes, there could be many homemade systems in place.

With an acceptable alternative on the market (i.e. a small volume ULC-approved fixed system), regulatory authorities could consider promulgating regulatory change prohibiting homemade systems.

As a result of this project, ANSUL has developed a ULC-approved system for 5 lb. and up. The ANSUL system was tested on two vessels in accordance to recommended guidelines and ULC standards, with acceptable results.

10. RECOMMENDATIONS

Recommendations of this project are to prohibit the use of homemade fire extinguishing systems that are based on modified portable fire extinguishers and to encourage the use of low-cost ULC-tested and approved systems that are now available.

It is also recommended that appropriate adjustments be made to the current regulations to reflect the availability of a ULC-approved system.

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- CSA-20: Fire Detection and Extinguishing Equipment Regulations
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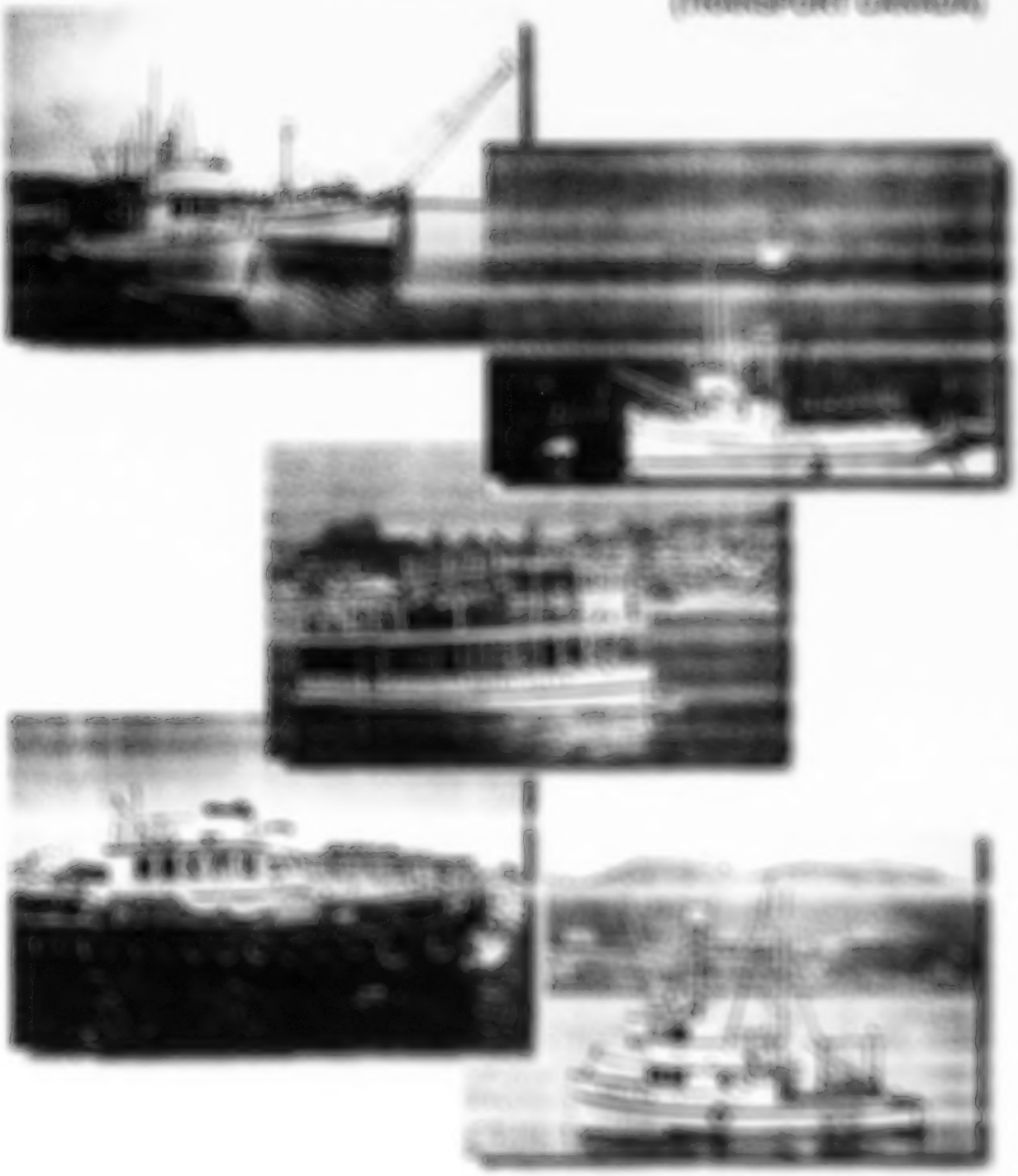
ANSUL

INSTALLATION, RECHARGE, INSPECTION AND MAINTENANCE MANUAL

MARINE PRE-ENGINEERED CARBON DIOXIDE FIRE SUPPRESSION SYSTEM (TRANSPORT CANADA)



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INTRODUCTION

⚠ CAUTION

This manual has been developed to assist small vessel owners in the design and installation of an Ansul Marine Pre-engineered CO_2 Fire Suppression System. Those who install, operate, recharge or maintain these fire suppression systems must read this entire manual. Specific sections will be of particular interest depending upon one's responsibilities.

The system design covers single compartment (engine room) hazards utilizing total flooding protection. Total flooding protection is defined as filling the compartment or room with a given concentration of CO_2 agent for an extended period of time in order to dilute the oxygen content of the protected hazard to a point where it will not support combustion.

APPROVALS

The system described and illustrated herein carry the approval of Underwriters Laboratories of Canada (ULC) for Marine use.

The CO_2 cylinders provided with this system are approved containers per Transport Canada (TC) and US DOT regulations.

Approval by the United States Coast Guard (USCG) for installations on small vessels is pending. If the system is to be installed per USCG requirements, the installation must be designed per the Ansul manual, Part No. 429553. The differences are:

1. The Ansul **recommended** maximum volumes stated in this ULC manual become mandatory per USCG.
2. Connected reserve cylinders are optional per USCG but mandatory for some vessels in Canada.

SAFETY PRECAUTIONS

Carbon dioxide is a colorless, odorless, electrically nonconductive inert gas that is a suitable medium for extinguishing fires. Liquid carbon dioxide forms solid dry ice (snow) when released directly into the atmosphere. Carbon dioxide gas is 1.5 times heavier than air. Carbon dioxide extinguishes fire by reducing the concentrations of oxygen in the air to the point where combustion stops.

⚠ CAUTION

The discharge of carbon dioxide in fire extinguishing concentration creates serious hazards to personnel, such as suffocation and reduced visibility during and after the discharge period. Consideration must be given to the possibility of carbon dioxide drifting and settling into adjacent places outside of the protected space. Consideration must also be given to where the carbon dioxide can migrate or collect in the event of a discharge from a safety relief device of a storage container.

In any use of carbon dioxide, consideration must be given to the possibility that personnel could be trapped in or enter into an atmosphere made hazardous by a carbon dioxide discharge. Suitable safeguards must be provided to ensure prompt evacuation, to prevent entry into such atmospheres, and to provide means for prompt rescue of any trapped personnel. Personnel training must be provided.

Personnel must not reenter the protected area until all carbon dioxide has been properly vented.

SYSTEM DESIGN

System design requires that the proper size CO_2 cylinder be utilized for the protected area. Four (4) sizes of cylinders are available:

Part No.	Size
427452	5 lb. (2.3 kg) CO_2 Cylinder Shipping Assembly
427453	10 lb. (4.5 kg) CO_2 Cylinder Shipping Assembly
427454	15 lb. (6.8 kg) CO_2 Cylinder Shipping Assembly
427455	20 lb. (9.1 kg) CO_2 Cylinder Shipping Assembly

To select the proper cylinder size, complete the following:

1. Carefully measure the engine compartment and calculate the gross volume. NOTE: Do not deduct any volume for the equipment located in the engine room.
2. After determining the engine room volume, see chart below (gas quantity as verified by ULC) to choose the recommended size cylinder. If the space to be protected is larger than the size that can be protected by a single 20 lb. (9.1 kg) CO_2 cylinder, contact an Ansul authorized distributor for the selection of the proper equipment.

Engine Room Volume	Maximum Longest Dimension	Cylinder Size Required
Up to 75 cu. ft. (2.1 cu. m)	20 ft. (6.1 m)	5 lb. (2.3 kg)
76 cu. ft. to 150 cu. ft. (2.2 cu. m to 4.2 cu. m)	20 ft. (6.1 m)	10 lb. (4.5 kg)
151 cu. ft. to 225 cu. ft. (4.3 cu. m to 6.4 cu. m)	20 ft. (6.1 m)	15 lb. (6.8 kg)
226 cu. ft. to 300 cu. ft. (6.5 cu. m to 8.5 cu. m)	20 ft. (6.1 m)	20 lb. (9.1 kg)

IMPORTANT

NOTE: The table above reflects U.S. requirements, the recommendations of Ansul Incorporated, and as tested and listed by ULC. Transport Canada (TC) requirements are different. Canadian vessel owners must see the Appendix Section for a summary of the Transport Canada (TC) regulations. These regulations allow larger volumes to be protected.

NOTES

- This system is intended and designed for the discharge of one CO_2 cylinder into one engine compartment.
- Manifolding of tanks is not allowed (other than to connect a reserve cylinder).
- Vessels with hulls other than steel (fiberglass, wood, etc.) require a connected reserve system. A shuttle valve is required and available for this purpose.
- Means must be provided for quick closure of all openings (i.e. dampers, vents, hatches and doorways) which admit air to or would allow the escape of CO_2 from the engine room.
- If the engine space is normally serviced by mechanical ventilation, the system should be installed with a pressure switch, Ansul Part No. 46250, to automatically shut down the mechanical ventilation upon discharge.
- Temperature range for the hazard area and the cylinder storage area is –20 °F to 130 °F (–29 °C to 54 °C).

GENERAL INFORMATION

- Cylinders must not be stored in the engine room.
- Install placard near cylinder and remote manual pull station.
- Cylinder valve is equipped with a bursting disc rated at 3000 psi (20.7 bar).
- Cylinders must not be stored in accommodation spaces.
- All cylinders can be vertically mounted in their bracket. The 5, 10, and 15 lb. (2.3, 4.5, and 6.8 kg.) can be horizontally mounted also. Note: The horizontal mounting must be to the deck (bottom) only, not to a bulkhead (side).
- The preferred storage location for cylinder(s) is in a dedicated storage box. This storage box should:
  - Provide protection from sea splash and mechanical damage.
  - Be vented to atmosphere.
  - Be easily opened for inspection.
  - Not be locked
  - Be fitted with drain holes
  - Hold cylinder(s) in a position at least 2 in. (51 mm) above the bottom of the box.
  - Be clearly marked as containing CO_2 cylinder(s).
  - Be regularly checked and kept clear of obstructions such as icing, piled ropes, tools, fishing gear, etc.
  - Be fitted with a placard identifying the procedure to be followed before discharge of the cylinder(s).

PIPE AND FITTINGS

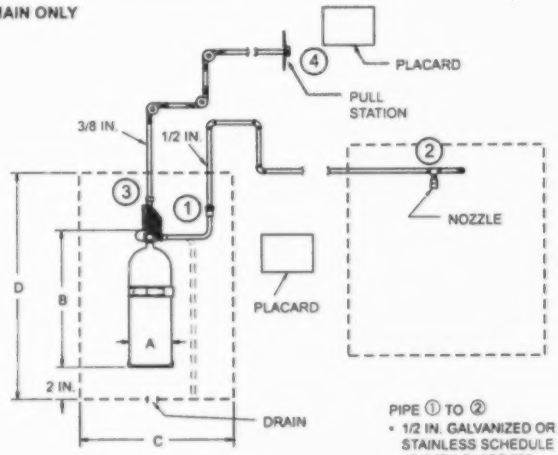
- The arrangement of the discharge piping must be designed to avoid trapping moisture.
- Pipe size must be 1/2 in. Schedule 40 galvanized steel or stainless steel.
- 12 in. (305 mm) discharge hose, Part No. 427267, must be used between the tank valve outlet and the discharge piping.
- Maximum pipe length must not exceed 50 ft. (15.2 m).
- Maximum number of elbows must not exceed 10.
- Acceptable pipe includes: ASTM A-63 seamless or electric welded, Grade A or B galvanized steel pipe, ASTM A-106, Grade A, B, or C galvanized steel pipe and TP-304 or TP-316 stainless steel pipe.
- An approximately 2 in. (51 mm) long dirt trap must be installed at the end of the pipe run.
- Pipe fittings must be Class 300 either malleable iron or ductile iron. Cast iron fittings must not be used.
- Pipe fittings must be either welded or American Standard pipe thread (NPT).
- Threaded joints must be reamed and free of burrs. After cutting, threading and reaming, pipe must be cleaned to remove oil, lacquer, scale and cuttings using a degreasing solution run through the pipe.
- Use pipe sealant on the male threads only.
- Pipe must be securely braced and fastened to the vessel structure. The maximum spacing between supports is 5 ft. (1.5 m).
- Piping must not be hung or supported from other piping.
- Support must be provided within 12 in. (305 mm) of the discharge nozzle.
- On vessels that require a connected reserve cylinder, a shuttle valve, Part No. 427266, is required and available for this purpose.
- Pipe penetrations through decks or bulkheads must not decrease the integrity and fire resistance of the decks or bulkheads. Pipe sleeves packed with fire resistant material should be used.

DISCHARGE NOZZLE

- Only one discharge nozzle is allowed per system.
- Opening of nozzle must aim at the center of the engine room.
- Nozzle must not be located adjacent to obstructions such as piping, beams, pillars, frames, or equipment items.
- Nozzle must not be located adjacent to vents, dampers, fans, hatches, or doorways (compartment escape routes).
- Nozzle is a baffle type, Part No. 426120-3.5, with a 3.18 mm orifice.

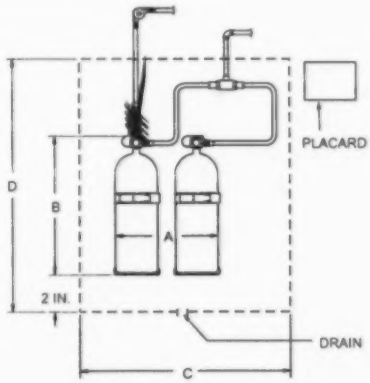
GENERAL ARRANGEMENT

MAIN ONLY



PIPE ① TO ②
- 1/2 IN. GALVANIZED OR STAINLESS SCHEDULE 40 WITH CLASS 300 FITTINGS
- LENGTH NOT TO EXCEED 50 FT. (15.2 m)
- NUMBER OF ELBOWS NOT TO EXCEED 10

MAIN AND RESERVE



PIPE ③ TO ④
- 3/8 IN. GALVANIZED OR STAINLESS SCHEDULE 40 WITH ANSUL PULLEY ELBOWS
- LENGTH NOT TO EXCEED 50 FT. (15.2 m)
- NUMBER OF ELBOWS NOT TO EXCEED 15

FIGURE 1
004381

GENERAL ARRANGEMENT (Continued)

Dimensions For Cylinder Installation

Main Only	Cylinder Width A	Cylinder Height B	Approx. Width of Enclosure C	Approx. Height of Enclosure D
5 lb. (2.3 kg)	5 1/4 in. (133 mm)	16 1/4 in. (413 mm)	9 1/4 in. (235 mm)	28 1/4 in. (718 mm)
10 lb. (4.5 kg)	6 3/4 in. (171 mm)	21 in. (533 mm)	10 3/4 in. (273 mm)	33 in. (838 mm)
15 lb. (6.8 kg)	6 3/4 in. (171 mm)	25 3/4 in. (654 mm)	10 3/4 in. (273 mm)	37 3/4 in. (959 mm)
20 lb. (9.1 kg)	7 3/4 in. (197 mm)	25 1/2 in. (648 mm)	11 3/4 in. (299 mm)	37 1/2 in. (952 mm)

Main and Reserve	Cylinder Width A	Cylinder Height B	Approx. Approx. of Enclosure C	Approx. Approx. of Enclosure D
5 lb. + 5 lb. (2.3 kg + 2.3 kg)	14 1/2 in. (368 mm)	16 1/4 in. (413 mm)	18 1/2 in. (470 mm)	28 1/4 in. (718 mm)
10 lb. + 10 lb. (4.5 kg + 4.5 kg)	17 1/2 in. (445 mm)	21 in. (533 mm)	21 1/2 in. (546 mm)	33 in. (838 mm)
15 lb. + 15 lb. (6.8 kg + 6.8 kg)	17 1/2 in. (445 mm)	25 3/4 in. (654 mm)	21 1/2 in. (546 mm)	37 3/4 in. (959 mm)
20 lb. + 20 lb. (9.1 kg+ 9.1 kg)	19 1/2 in. (495 mm)	25 1/2 in. (648 mm)	23 1/2 in. (597 mm)	37 1/2 in. (952 mm)

INSTALLING THE CYLINDER

The 5 lb., 10 lb. and 15 lb. (2.3 kg, 4.5 kg and 6.8 kg) cylinders can be installed in both the vertical and horizontal position. **The 20 lb. (9.1 kg) cylinder can only be mounted in the vertical position. The cylinder bracket must be securely bolted or welded to a rigid surface.**

	Mounting Positions	
5 lb. (2.3 kg)	Vertical	Horizontal
10 lb. (4.5 kg)	Vertical	Horizontal
15 lb. (6.8 kg)	Vertical	Horizontal
20 lb. (9.1 kg)	Vertical	~~Horizontal~~

When mounting in the horizontal position, the safety relief valve must be located in the down position. See Figure 2. This is necessary to insure that the internal pick up tube is correctly oriented for the horizontal discharge position.

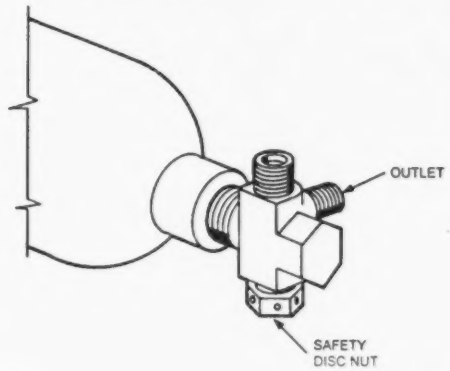


FIGURE 2
004362

PIPING AND NOZZLE INSTALLATION

Once the cylinder bracket has been securely mounted, position the cylinder in the bracket and tighten securely. Attach the 12 in. (305 mm) discharge hose, Part No. 427267, to the cylinder valve outlet. See Figure 3. **NOTE: The discharge hose must be utilized in the system piping. If it is not used, the system will not discharge when the valve is opened.** If the system requires a connected reserve cylinder, see INSTALLING THE SHUTTLE VALVE. If a shuttle valve is not required, install the discharge piping and nozzle.

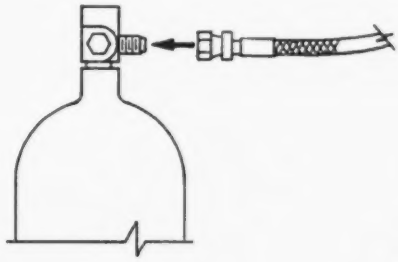


FIGURE 3
004363

INSTALLING THE SHUTTLE VALVE

The shuttle valve, Part No. 427266, is required on systems requiring a connected reserve cylinder. (Vessels with hulls other than steel may require a connected reserve system). Install the shuttle valve as shown in Figure 4. After the shuttle valve has been installed, install the discharge piping and the nozzle.

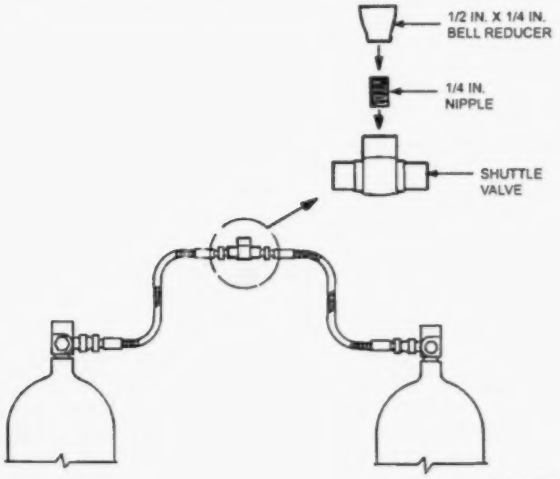


FIGURE 4
004377

INSTALLING THE ACTUATOR

Install actuator, Part No. 427675, on cylinder valve. Make certain actuator lever is in the SET position and the pin is sealed in the lever. See Figure 5.

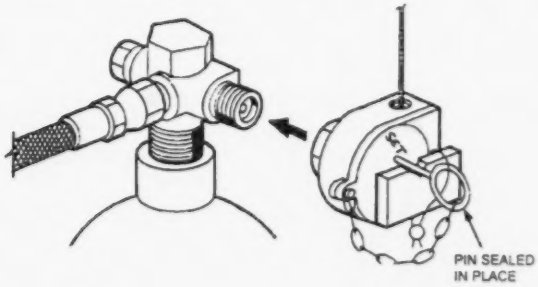


FIGURE 5
004365

INSTALLING THE MANUAL PULL STATION(S)

NOTICE

If the system is installed in a readily accessible location, a manual pull station is not required. In such cases, the ring pin should remain sealed in place and removed only when system operation is required. Also, cut actuator cable off flush with body of actuator.

The manual pull station(s) must be located at a point of exit, outside the engine room. For protection of the cable, the cable should be run in 3/8 in. galvanized pipe. Make certain that all ends are carefully reamed, deburred and blown clear of chips and scale before assembly.

The total length of cable used for each pull station is 50 ft. (15.2 m) maximum and the maximum number of pulley elbows allowed is 15 per each pull station. The maximum pull force required is 40 lb. (18 kg).

1. Install piping from pull station(s) location to location of the cylinder. Use pulley elbow, Part No. 45515, when making any change of direction. Terminate the threaded end of the pipe 6 in. to 8 in. (152 to 203 mm) from the actuator. See Figure 6. See Steps No. 2 or 3 depending on the type of installation used.

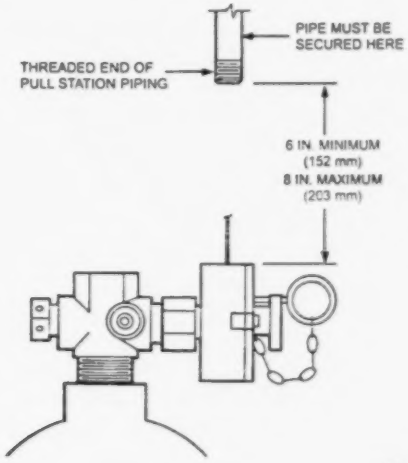


FIGURE 6
004366

2. If a 4 in. (102 mm) junction box is used, see Figure 7 for mounting details.

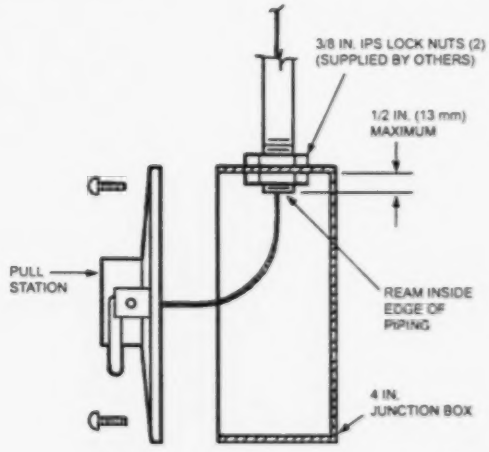


FIGURE 7
004367

INSTALLING THE MANUAL PULL STATION(S) (Continued)

3. If no junction box is used, see Figure 8 for mounting details.

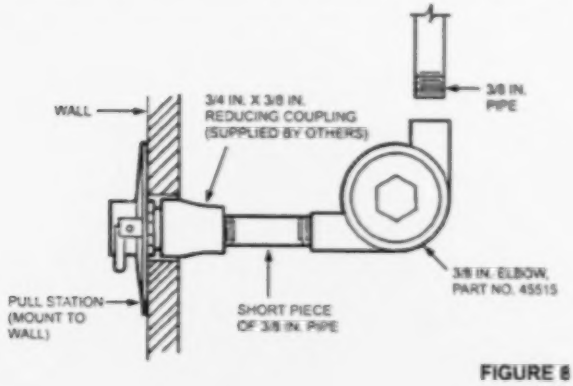

WALL
3/4 IN. X 3/8 IN. REDUCING COUPLING (SUPPLIED BY OTHERS)
3/8 IN. PIPE
3/8 IN. ELBOW, PART NO. 45515
PULL STATION (MOUNT TO WALL)
SHORT PIECE OF 3/8 IN. PIPE

FIGURE 8

NOTE: On connected reserve systems, a separate manual pull station is not required for the reserve cylinder if it can be rapidly manually actuated.

4. Attach flared end fitting, Part No. 40060, to threaded end of 3/8 in. pipe. See Figure 9.

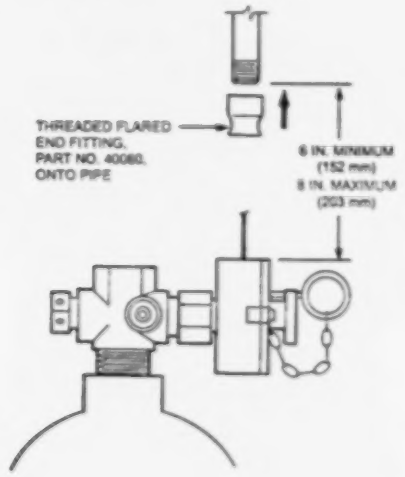


FIGURE 9

5. Route cable from pull station through 3/8 in. pipe and pulley elbows to cylinder valve.
6. Mount pull station before attaching the cable to the actuator cable.
7. Attach cable to actuator cable using split bolt connector included with pull station. See Figure 10.

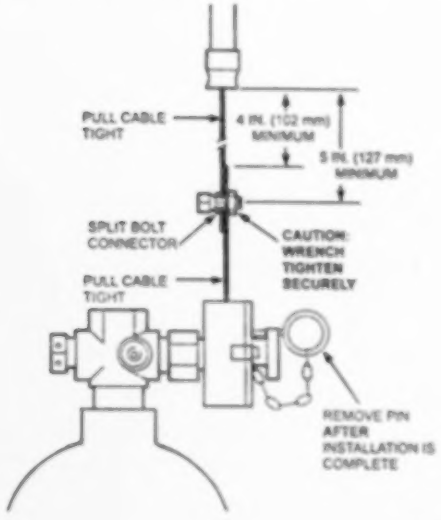

PULL CABLE TIGHT
4 IN. (102 mm) MINIMUM
5 IN. (127 mm) MINIMUM
SPLIT BOLT CONNECTOR
CAUTION: WRENCH TIGHTEN SECURELY
PULL CABLE TIGHT
REMOVE PIN AFTER INSTALLATION IS COMPLETE

FIGURE 10

8. After all installation steps have been completed, **arm the system** by removing the pin from actuator. **NOTE: If pin is not removed, system will not actuate when pull station is operated.**

OPERATION

In Case Of Fire

1. Manually shut-off engine.
2. Shutdown ventilation and close all openings (vents, hatches, dampers, etc.).
3. Make certain all personnel are out of the hazard area.
4. Pull handle on remote pull station or turn lever on cylinder valve actuator to the OPEN position. See Figure 11.

REMOTE RELEASE DIRECT CYLINDER RELEASE

FIGURE 11

5. After the CO_2 discharge has ended (on systems where the local regulations require a connected reserve), if the fire is not completely extinguished, turn lever on reserve cylinder valve actuator to the OPEN position.
6. Stand by with a hand portable extinguisher.
7. After the fire is extinguished, before entering the protected space, ventilate the engine room for a minimum of 15 minutes or for a sufficient amount of time for one complete air change.

SHUT-DOWNS

For the system to extinguish a fire, the engine must be stopped, ventilation must be stopped, and all openings must be closed, before the CO_2 system is released. These shutdown actions may be performed manually. If automatic shutdown is required, pressure switches to open electrical circuits, and pressure operated damper releases can be installed. These are optional devices.

INSPECTION

Inspection is a "quick check" that a system is operable. It is intended to give reasonable assurance that the system is fully charged and will operate. This is done by seeing that the system has not been tampered with and there is no obvious physical damage, or condition, to prevent operation. The value of an inspection lies in the frequency, and thoroughness with which it is conducted. Systems should be inspected at regular monthly intervals or at more frequent intervals when circumstances require.

The following visual checks should be performed during a CO_2 system inspection:

MANUAL PULL STATION

Check that it has not been tampered with and is ready for operation. Seals or break rod must be in place. Check that all piping, cable, and pulley elbows between the pull station and the cylinder are not damaged, loose, or corroded.

CYLINDER

Check that the mounting bracket(s) are secure. Visually check cylinder for any dents or signs of corrosion. Check nameplate on the cylinder to make certain it is securely attached and readable.

CYLINDER ACTUATOR

Check that the actuator is in place and the lever is in the SET position. Make certain pin has been removed from the actuator if remote manual pull station is installed.

SYSTEM PIPING AND NOZZLES

Check that the piping is secure and the nozzle is in place. Make certain the nozzle is not covered with dirt, grease, or paint. Make certain the nozzle is aimed in the proper direction. Check that the nozzles are not obstructed by equipment.

PLACARDS

Check to see that all instruction placards are securely in place, not blocked from view, and clearly readable.

MISCELLANEOUS

Make a check list of details that are important to the system which are not discussed above, i.e., has the hazard size or configuration been changed? Are dampers, hatches, or doors held open where they shouldn't be? Are instruction placards in place? Are there any conditions that would hinder the operation of the system?

RECORDS

Personnel making inspections should keep records for the extinguishing system for items that were found to require corrective action. At least monthly, the date the inspection was performed and the initials of the person performing the inspection should be recorded.

[redacted]

Systems must be maintained at regular intervals, not more than twelve (12) months apart, or when specifically indicated by an inspection. Maintenance is a "thorough check" of the system. It is intended to give maximum assurance that a system will operate effectively and safely. It includes a thorough examination and any necessary repair, recharge, or replacement. It will normally reveal if there is a need for hydrostatic testing of the tank.

Because of the age, the cylinder may require hydrostatic testing. Refer to NFPA12, "Standard on Carbon Dioxide Extinguishing Systems," for detailed instructions concerning hydrostatic test requirements.

All of the steps called out in the INSPECTION SECTION should be performed in the six-month Maintenance Examination. Along with those steps, the following addition steps must be completed:

1. Insert pin into actuator and remove the actuator from the cylinder valve.
2. Remove the cover from each pulley elbow and check to see that the wire rope is correctly positioned in the pulley sheave. Return cover to elbow.
3. Disconnect the discharge hose from the cylinder valve and remove the cylinder from the bracket. Weigh cylinder. Verify the weight against the full weight stamped on the cylinder valve. See Recharge Section, Page 10, for correct weight tolerances.
4. Return the cylinder to the bracket, secure firmly, and reconnect the discharge hose.
5. Check lever on actuator to make certain it is in the SET position (notch on lever must be located over the word SET).
6. Reinstall actuator on cylinder valve and wrench tighten securely.
7. Remove pin from actuator.

⚠ CAUTION

If pin is not removed from actuator, system will not discharge when pull station is operated.

[illegible]

For continuous fire protection, the Marine Pre-Engineered CO_2 System must be recharged immediately after use.

NOTICE

Determine the cause of the system discharge and correct it immediately before performing system recharge.

To recharge the cylinder, the recharge must have a discharge hose, Part No. 607287, and an actuator, Part No. 607976. Without these components, the valve cannot be held open during recharging.

⚠ CAUTION

During recharge, cylinder must be chilled so that the valve is protected from damage.

To recharge the cylinder, complete the following steps:

1. Turn actuator to the SET position, and pin in actuator and remove the actuator from the empty cylinder.
2. Disconnect the discharge hose from the cylinder valve.
3. Remove the empty cylinder from the bracket.
4. Cylinder must be recharged by an authorized threat distributor.
5. To complete the recharge:
   - Install actuator to discharged cylinder and turn actuator handle to the OPEN position.
   - Install discharge hose to valve outlet. NOTE: Discharge hose must be attached to valve in order to keep outlet open during filling.
   - Attach fill station hose to discharge hose. Position empty cylinder on scale and proceed to fill. The following fill determinations apply:

     2 lb. (0.9 kg) Cylinder = 5 lb. (2.3 kg) CO_2 = 5 oz. (110 g)

     10 lb. (4.5 kg) Cylinder = 10 lb. (4.5 kg) CO_2 = 5 oz. (110 g)

     15 lb. (6.8 kg) Cylinder = 15 lb. (6.8 kg) CO_2 = 8 oz. (227 g)

     20 lb. (9.1 kg) Cylinder = 20 lb. (9.1 kg) CO_2 = 8 oz. (227 g)

   - After cylinder is full, turn lever on cylinder valve actuator to the SET position. This will close the cylinder valve.
   - Remove discharge hose from valve outlet.
   - Check valve outlet and actuator port for leaks using a soap solution.
   - Cylinder is now ready to be placed back into the system.
6. Secure the recharged cylinder into the bracket.
7. Attach the discharge hose to the valve outlet. Wrench tighten securely.
8. Make certain actuator is pinned in the SET position and install actuator to cylinder valve. Wrench tighten securely.
9. Remove broken glass rod from pull station / apparatus and discard. Insert new glass rod in pull station.
10. Remove pin in cylinder actuator. Do not move handle from SET position.

⚠ CAUTION

If pin is not removed from actuator, system will not discharge when pull station is operated.

11. Verify personnel that the fire suppression system is back in service and record the date of recharge.

[illegible]

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